TERRESTRIAL MAGNETISM

AND

ATMOSPHERIC ELECTRICITY

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ATMOSPHERIC ELECTRICITY

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PRELIMINARY REPORT ON THE RESULTS OF THE AURORA-POLARIS EXPEDITION TO BOSSEKOP IN THE SPRING OF 1913.

BY CARL STÖRMER, *Kristiania.*

1. In this Journal for September, 1913, I gave a short account of an aurora-polaris expedition which I made to Bossekop in the spring of 1913, for the purpose of completing the results of my expedition to the same place in 1910.

The working up of the very extensive material from this expedition has since been continued, but only one sixth of the whole has been finished. This nevertheless gives about 600 very exact measurements of the altitude of the aurora and of its position in space. The material considered is from the nights of March 3-4, 4-5, and 11-12, 1913. From the last of these nights, especially, we have a large number of very interesting observations.

Each aurora was photographed simultaneously from the two stations, Bossekop and Store Korsnes, lying at a distance of 27.5 kilometers from each other, almost in a north and south line, and connected by telephone. The parallaxes vary from 2° for the most distant auroras to 15° for those near the zenith. The computations have been carried out by the methods published in my report of 1910.[1]

The observations for the year 1913 should be of special interest, since we have a very marked minimum of solar activity for that year. It was to be expected that the auroral corpuscles, being supposed to come from the Sun, would have very little penetrating power and would be stopped high up in the atmosphere. This proved, indeed, to be the case, as may be seen in Fig. 1, which represents graphically the altitudes above the Earth's surface of all the auroral points that have been calculated. It will be seen that *there is a very striking lower limit of 90 to 100 kilometers.*

[1] Bericht über eine Expedition nach Bossekop zwecks photographischer Aufnahmen und Höhenmessungen von Nordlichtern. *Videnskabsselskabets Skrifter*, 1911; Kristiania.

For each auroral point, the point on the surface of the Earth lying in the same Earth-radius has been found. The distribution of all the calculated points is shown in Fig. 2. The cumulation in certain directions (seen from Bossekop) is due entirely to certain prominent stars in those directions, stars toward which the cameras were pointed.

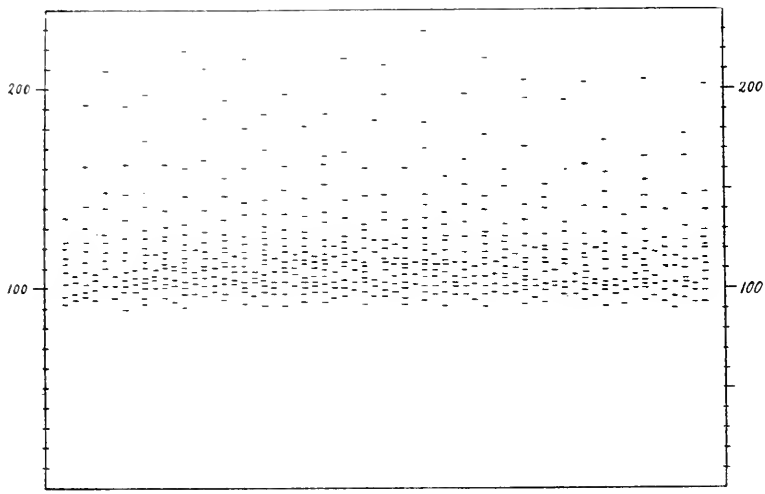
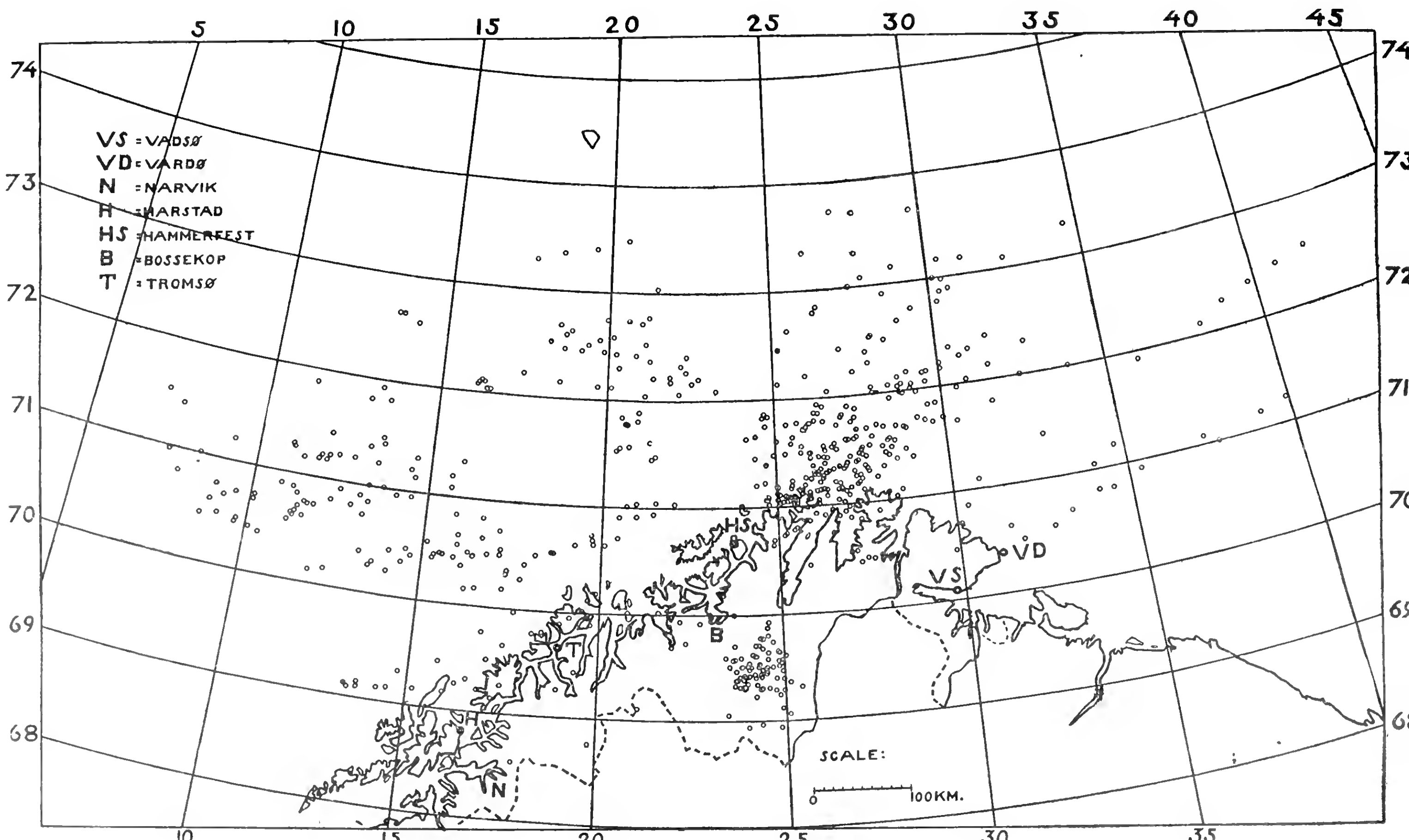


FIG. 1.

It has been especially interesting to draw the most prominent arcs and curtains in order to see the directions of these auroral displays. These directions are shown in Fig. 3. They form a relatively large angle, with the magnetic meridian at Bossekop, which is about 2.5° west of true north.

2. We have thought it might be interesting to give the altitudes and positions from some of the most remarkable pairs of photograms published in some of the earlier reports of the expedition. The first of these is of the aurora-curtains of March 3, 1913, at 10^{h} 36^{m}, central European time. The photographs were published in *Comptes Rendus* for June 16, 1913, and also in the *Bulletin de la Société Astronomique de France* for November of the same year. Fig. 4 shows a sketch from the negatives, with the chosen points numbered from 1 to 20. Each point is connected by a dotted line with the corresponding position of the same point seen from Store Korsnes. The length of this line is then the parallax.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H = HARSTAD
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FIG. 2.

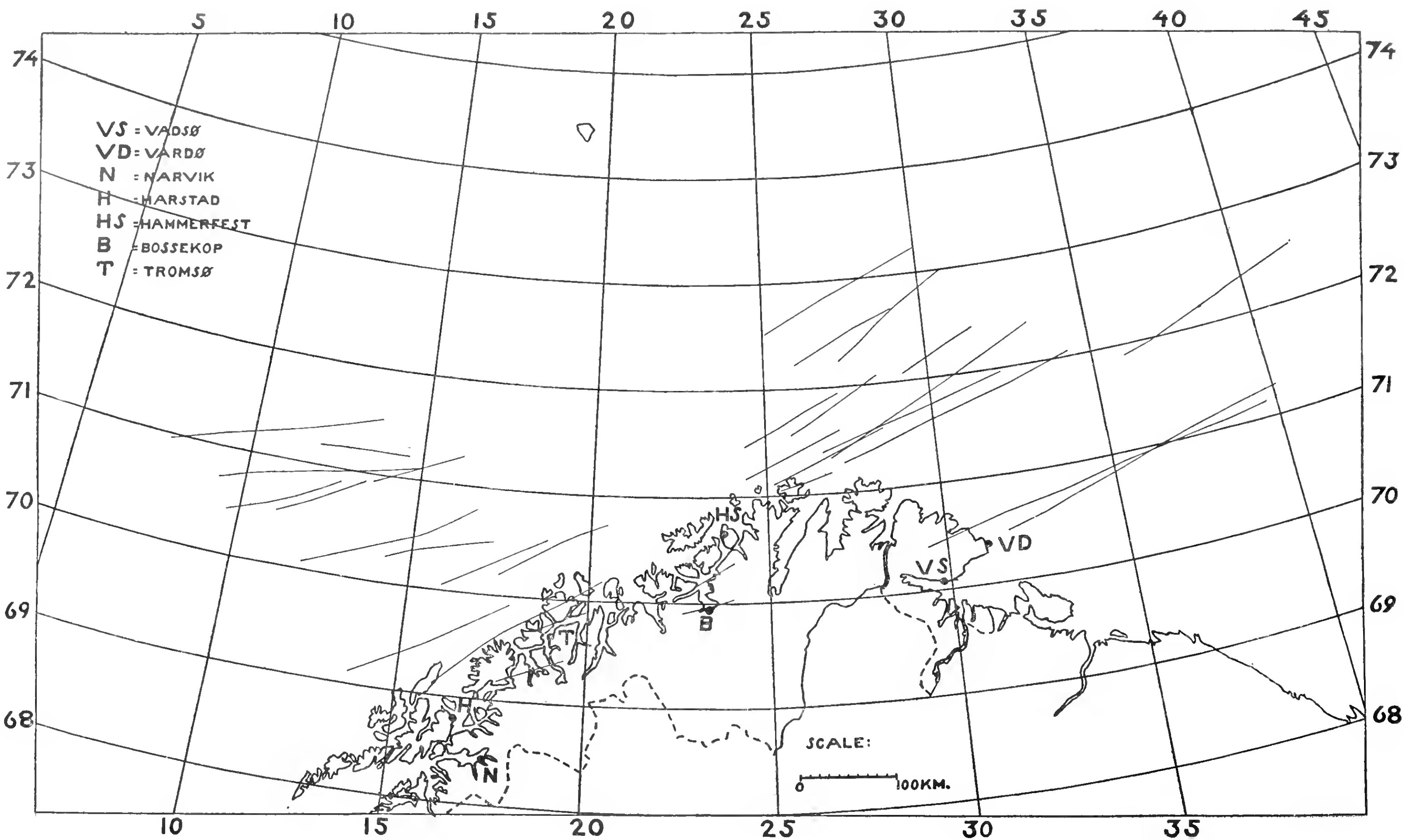
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Fig. 3.

The altitudes of these points were, in kilometers:

Number....	1	2	3	4	5	6	7	8	9	10
Altitude....	108	92	101	101	111	91	121	131	92	102
Number....	11	12	13	14	15	16	17	18	19	20
Altitude....	101	110	99	111	111	108	118	123	120	115

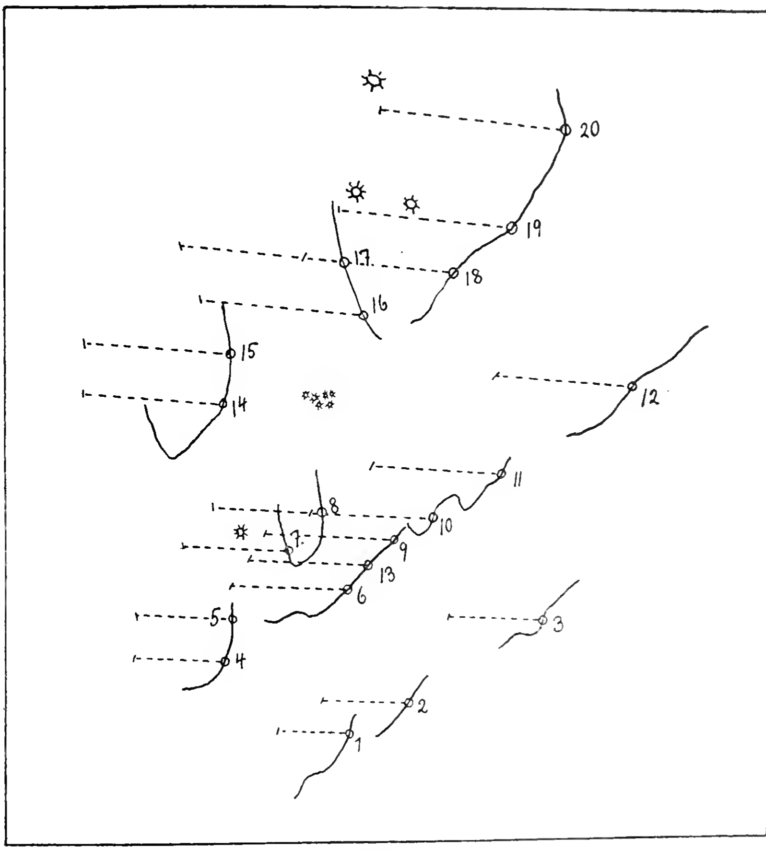

FIG. 4.

Their positions, projected on the surface of the Earth in the manner explained, are shown in Fig. 5. We have clearly three curtains, one behind the other, with an interval of about 60 kilometers.

The next two photograms belong to a most interesting series of photographs of a very remarkable aurora on the night of March 11-12. After a period of faint coruscating auroral bands through

the zenith from about 12 h 15 m to 12 h 30 m, there suddenly appeared in the west a very intense auroral drapery which rapidly developed eastward, passed near the zenith, and continued toward the north-east. The first photogram was taken at 12 h 32 m 40 s and the last at 12 h 36 m 32 s. At 12 h 34 m 40 s the auroral drapery was in the zenith of Store Korsnes. The color of this drapery was greenish white, and the intensity was so great that we obtained good pictures with an exposure of only one second in some cases. Even

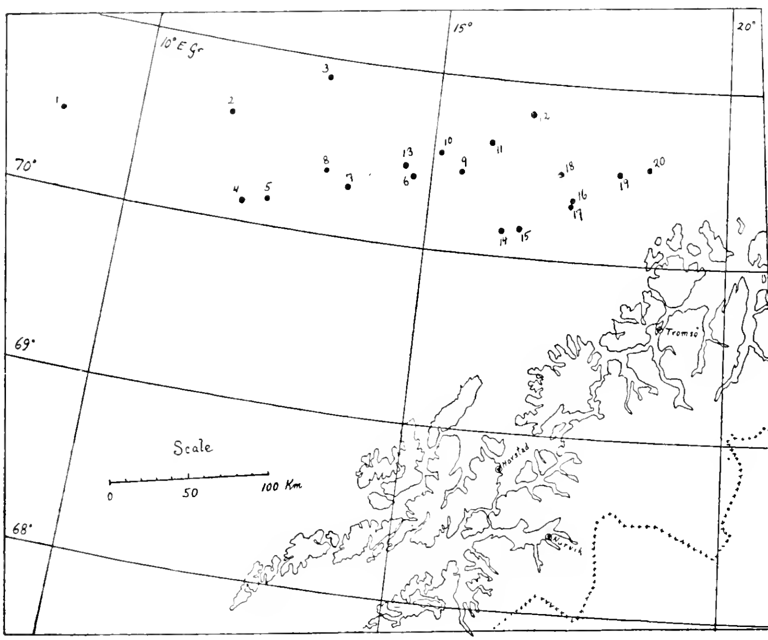

FIG. 5.

with a kinematograph we got usable pictures on the film with an exposure of about 0.3 second. The passing of this drapery over the sky was a very distinct and marked phenomenon, which offered a favorable opportunity for investigation of the nature of the aurora. We will return to this matter later.

Fig. 6 shows the successive positions of the drapery, drawn from the calculated photograms. The calculated points are marked for the two instants 12 h 33 m 17 s and 12 h 36 m 32 s. When the aurora was in the zenith of Store Korsnes, a picture was taken at each station, but only one of them was successful. Only the direc-

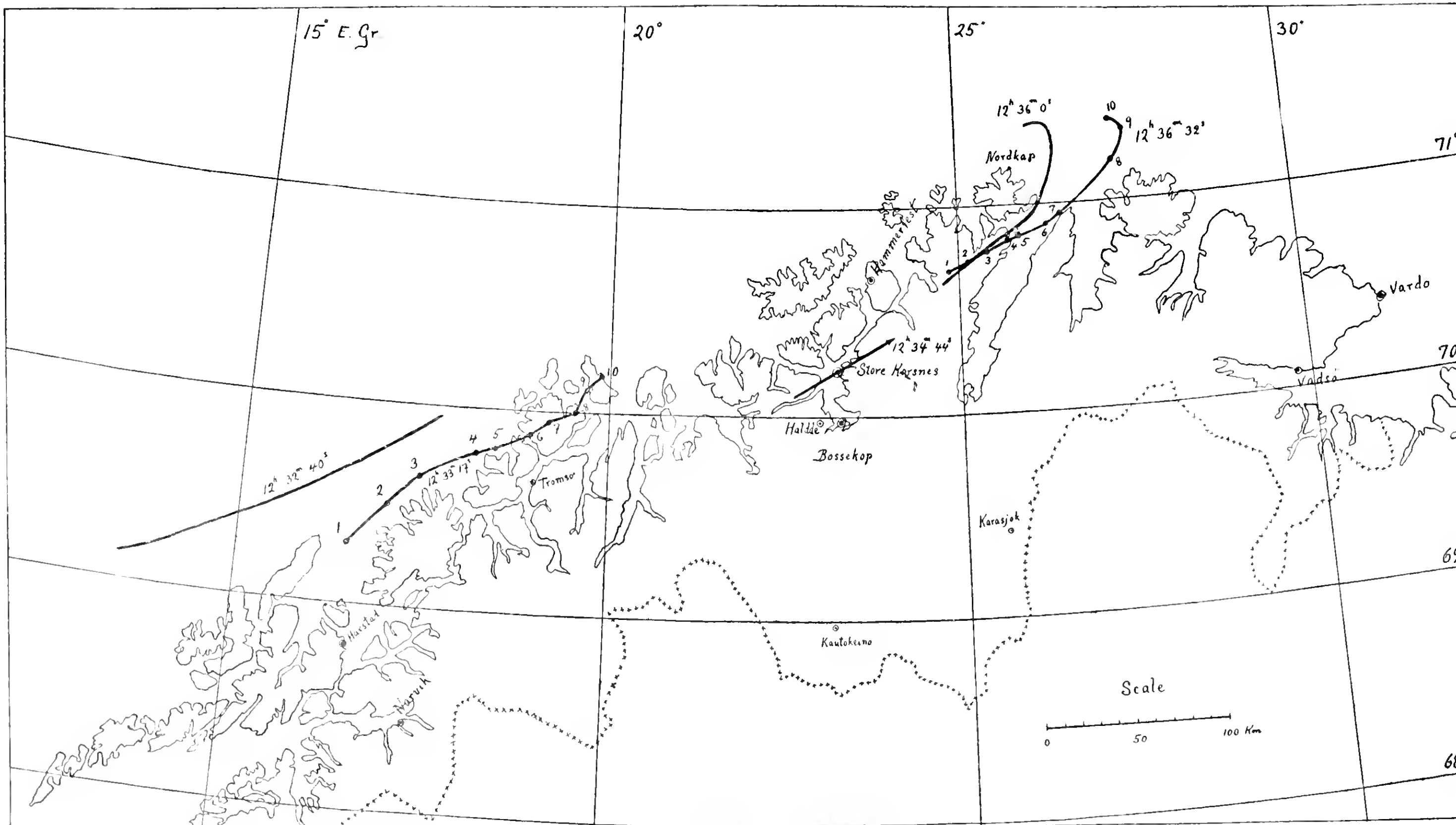
15° E. Gr.
20°
25°
30°
71°
70°
69°
68°
12h 36m 0s
12h 36m 32s
Nordkap
Hammerfest
12h 34m 44s
Store Korsnes
Haldde
Bossekop
12h 32m 40s
12h 33m 17s
Tromsø
Karasjok
Kautokeino
Harstad
Narvik
Vardø
Vadsø
Scale
0
50
100 Km

FIG. 6.

tion of the drapery, therefore, is given at that moment; but this direction is quite in harmony with the other positions shown in Fig. 6.

Two pictures of this aurora have already been published in my earlier reports, one in the *Astrophysical Journal* of November, 1913, the other in this Journal, Pl. VI, vol. 17, 1913. We give the calculated points for these two pictures. Fig. 7 shows a sketch, from the negatives, of the drapery at $12^h\,33^m\,17^s$ (Pl. VI, *Astrophys. Jour.*).

The calculated altitudes in kilometers were:

Number....	1	2	3	4	5	6	7	8	9	10
Altitude....	93	96	102	96	102	99	100	104	110	113

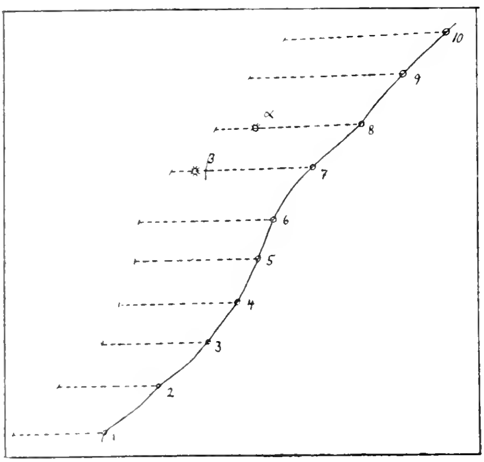

FIG. 7.

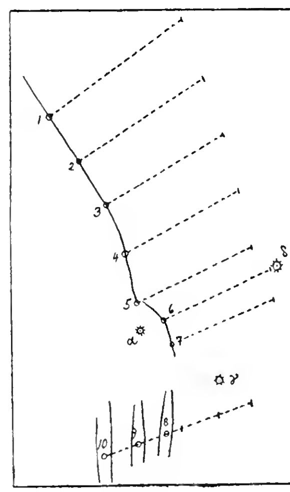

FIG. 8.

The position is shown in Fig. 6. Fig. 8 is a sketch of the drapery at $12^h\ 36^m\ 32^s$ (Plate VI in *Terrestrial Magnetism*).

The position is shown in Fig. 6. The heights in kilometers are here:

Number....	1	2	3	4	5	6	7	8	9	10
Altitude....	104	107	106	105	97	102	103	101	106	102

When this picture was taken, we had no more plates ready, and were obliged to wait until new ones could be put in the holders. The photographing was continued at $12^h\ 52^m$. At that time, the sky in the south was covered with the most remarkable, luminous, tranquil areas, mixed with rays and dark openings. The whole

remained almost unchanged for several minutes and was a very good object for the cameras. Five successful photograms were taken between 12^h 52^m 30^s and 13^h 1^m 14^s; they all show that there was very little change in the general form of this aurora, and the computation of its position showed that it remained almost stationary over a region 80 kilometers southeast of Bossekop. The altitude was about 100 kilometers.

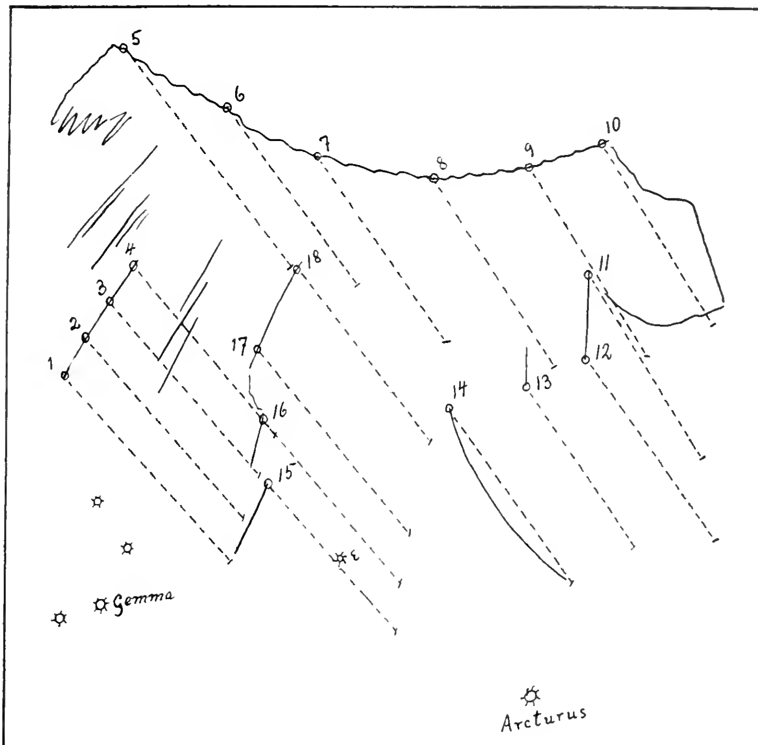

Fig. 9.

The first photogram of this remarkable aurora was published in the *Astrophysical Journal, c.*, as Plate VII; Fig. 9 shows a sketch of it. The altitudes in kilometers were:

Number....	1	1	3	4	5	6	7	8	9	10
Altitude....	96	103	109	118	111	132	118	114	117	120
Number....	11	12	13	14	15	16	17	18		
Altitude....	117	101	116	106	112	106	98	115		

2

In Fig. 10 we see the projected points on the Earth's surface. The cumulation of the points in the same region, as seen in Fig. 2, is due to the other photograms of this same aurora.

3. As I have already said, the auroral drapery moving eastward, on the night of March 11-12, 1913, seemed to afford a good opportunity for an investigation of the nature of auroras. If the magnetic action of this drapery could be found, we might be able

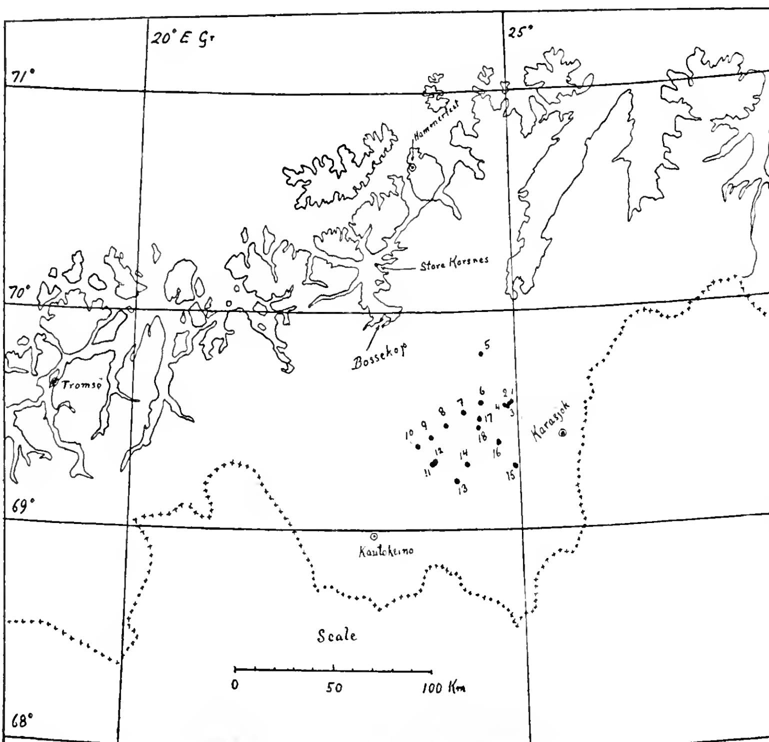

FIG. 10.

to decide whether it is negative or positive electricity moving downward in the drapery, because its exact position in space is known from the photograms. I wrote to Mr. Krogness, who is the director of the Haldde Observatory, and he was kind enough to send me the desired magnetograms for the night in question. Haldde is about 13 kilometers west of Bossekop, as may be seen from Fig. 6. Fig. 11 reproduces the magnetic curves for the time in question. In Fig. 12 is given all necessary information. The

instrument giving the vertical intensity had little sensibility at the moment compared with the instruments giving the declination and the horizontal intensity.

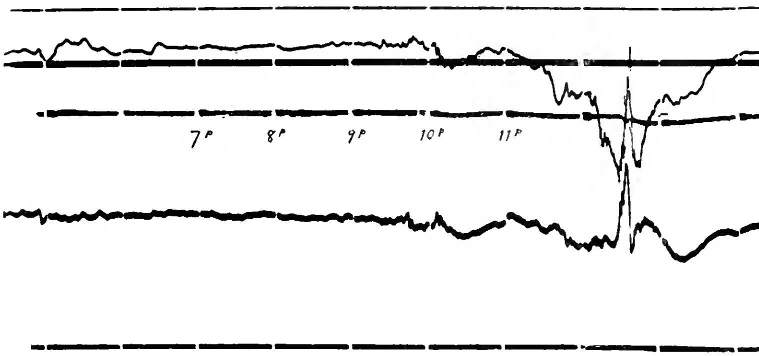

FIG. 11.

Now, the passing of the drapery is marked on the magnetograms by a very characteristic movement upward for two of the curves; for the third, representing the vertical intensity, we have a slight motion downward.

In order to find the direction of the perturbing force, due to the drapery, we have chosen the instant $12^h\ 36^m\ 30^s$, marked in

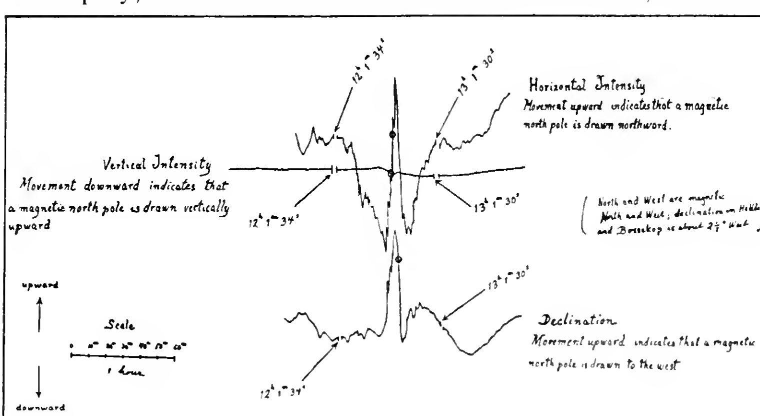

FIG. 12.

Fig. 12 by a small circle on each of the three curves. From this we conclude that the magnetic action was so directed that it had components pointing to the north, west, and upward. At the same instant the lower border of the drapery was in the position shown in Fig. 6. Now, the electric corpuscles most probably descend into the atmosphere from without, along the magnetic lines of force, forming auroral rays, which combine to form the drapery.

The simple application of Ampère's law then gives, as shown in Fig. 13, a magnetic action like that observed, if we suppose positive electricity coming down along the rays of the drapery, but an opposite action if negative electricity comes down.

It seems thus to be proved that the aurora was caused by positively-charged electric particles. In this connection there is a very large field for theoretical considerations. The mathematical theory of auroras which I have worked out in several memoirs[2] can be applied to the case of negative corpuscles as well as to that of positive

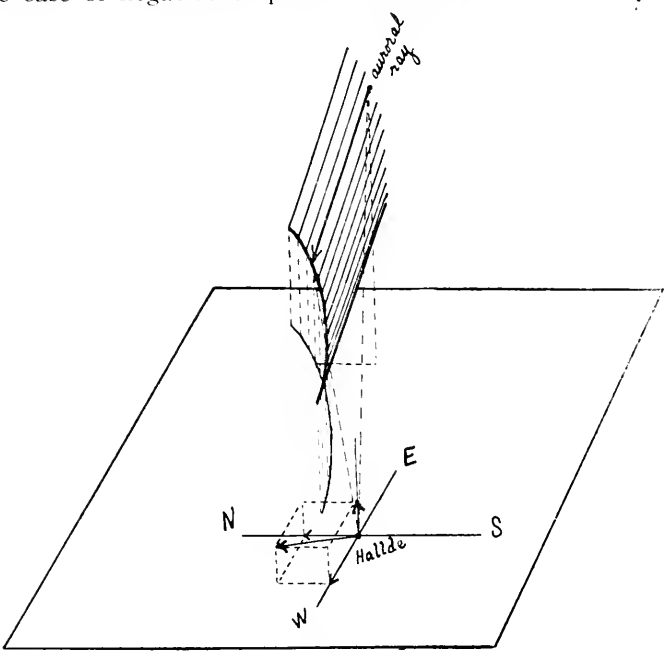

FIG. 13.

corpuscles. In my memoir in *Archives des Sciences physiques et naturelles*, Geneva, 1907, I had already made computations for both cases. The hypothesis that we have positive particles has later been elaborated by Dr. Vegard[3], who brought forward a series of arguments in favor of this assumption. The hypothesis of negative corpuscles was put forward by Paulsen and more especially by Professor Kr. Birkeland in 1896 and 1899-1900.[4] I think it best to wait until the whole material has been worked up before entering into a detailed comparison between observation and theory.

[2] See especially my memoir, "The Corpuscular Theory of Aurora Borealis," in the inaugural lectures of the Rice Institute.

[3] On the properties of the rays producing Aurora Borealis, *Phil. Mag.*, Feb., 1912.

[4] *Videnskabsselskabets Skrifter*, 1902, Kristiania, and *The Norwegian Aurora Polaris Expedition*, 1902-1903.

THE ATMOSPHERIC-ELECTRIC OBSERVATIONS ON THE THIRD CRUISE OF THE *CARNEGIE*, 1914.

REPORT AND DISCUSSION BY W. F. G. SWANN.

The general course followed by the *Carnegie* during her third cruise is shown on the accompanying map, Fig. 1. The vessel started from Brooklyn, under the command of Mr. J. P. Ault, on June 8, 1914, arriving at Hammerfest on July 3. Sailing again from Hammerfest on July 25, she arrived at Reykjavik, Iceland, on August 24, having reached the latitude of 79° 52′ North, off the northwest coast of Spitzbergen. Leaving Reykjavik on September 15, the *Carnegie* arrived at Greenport on October 12, returning to Brooklyn on October 21, 1914.

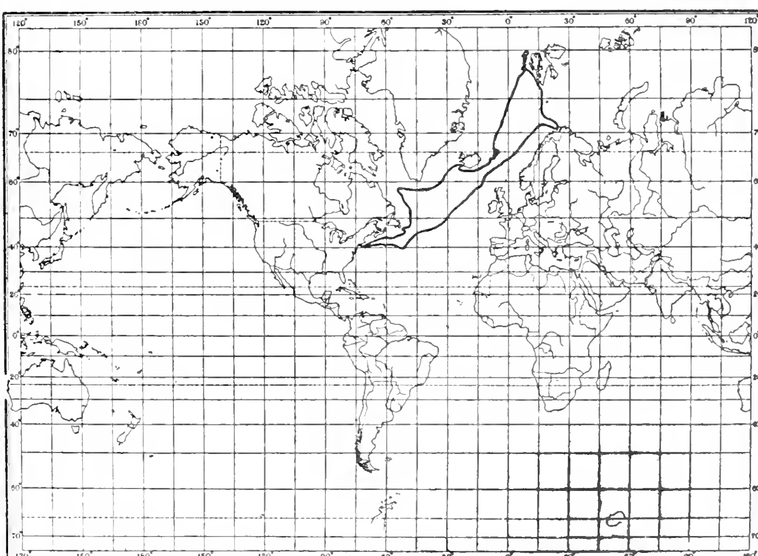

FIG. 1. *The Track followed by the Carnegie on her Third Cruise, 1914.*

The observations discussed in this report comprise, in addition to the meteorological data, measurements of the potential-gradient, the conductivities for the positive and negative ions, and the radioactive content. Measurements of the ionic numbers were also made during the passage from Greenport, through Long Island Sound, to New York. The whole of the observations, with the exception of a few measurements in Long Island Sound by the author, were taken by Observer H. F. Johnston.

Instruments and Methods.

The Potential-gradient. This element was measured in the manner adopted on the second cruise of the *Carnegie*, viz., by means of an ionium collector which was insulated and fastened to the end of a bamboo pole projecting from the stern rail of the ship. The potential of the collector was measured by a Wulf bifilar electroscope, the outer casing of which was connected to earth by means of a weighted wire hanging in the sea. The chief disadvantages of the collector form of instrument are to be found in the following facts. In the first place, an ionium collector may require something of the order of two minutes to attain a potential within a volt of its final steady potential. It will be obvious that since in the final state there will be a difference of potential of the order of 200 or 300 volts between the collector and the earthed bamboo pole, unless the insulation of the collector is perfect, the final potential of the collector will not have its proper value. It will have a value somewhere between zero and the proper value, and will be determined by the fact that the current of electricity flowing from the collector to earth over the leaking insulation, is equal to the current which is able to flow from the air to the collector due to the latter being at a potential below its proper amount. A simple calculation will show that even the electrical dispersion from the wire leading to the collector is sufficient to maintain it below its proper potential by an amount which may be serious, when it is of a slowly acting type.

In order to overcome the above difficulties, a new form of apparatus was devised by the author,[1] depending for its action on the alteration in potential experienced by a conductor when its position in the Earth's electric field changes. Owing to the fact that it became necessary to change the type of electroscope used with this instrument during the cruise, the second type being less sensitive than the first, the sensitivity of the apparatus was hardly sufficient for the purposes required of it, so that it was not used as extensively as the ionium collectors. In the fourth cruise, now in progress, this apparatus has been replaced by another depending on the same principle; the design of the instrument has been slightly altered, however, in order to render it more adaptable to other requirements necessitated by its being used in somewhat limited space in a position where it is liable to get in the way of the ropes. The alteration in design also embodies greatly increased sensitivity,

[1] *Terr. Mag.*, vol. 19, p. 171, September, 1914.

so that, indeed, it is quite easy to cause the normal potential-gradient to produce a deflection on the electroscope amounting to the whole of the scale length.

Since the atmospheric-electric elements vary considerable throughout the day, and since it was not feasible to measure the potential-gradient throughout the whole day, the measurements were made at about the same time as the conductivity observations. In this way a value of the potential-gradient was obtained which was suitable for combining with the conductivity to obtain the earth-air current.

The atmospheric-electric observations were always taken about the same time of day, between 9 A. M. and 12 noon. The standardization of the potential-gradient apparatus was made by simultaneous ship-and-shore observations on two occasions, the first at Reykjavik, and the second at Gardiner's Bay. In the shore observations a method due to Simpson [2] was employed, in which the ionium collector was fastened to the middle of a long wire stretched horizontally between two poles. It is very essential to have clear weather for a standardization of the potential-gradient apparatus, for it seems that if the sky is overcast, it is quite possible, apparently, to have large differences in the value of the potential-gradient at points about one mile apart; it is usually not very easy to arrange the ship-and-shore stations nearer together than this distance. Accordingly, the reduction of the relative values of the potential-gradient to absolute ones has been made with the aid of the factors derived, for the different positions of the sails, from the standardization observations at Reykjavik on September 11 and at Gardiner's Bay on October 18, both of these days being clear ones.

The conductivity. The conductivity was measured by Gerdien's method, a bifilar Wulf electroscope being employed. The clockwork fan associated with the apparatus draws such a small current of air that care had to be taken to employ a sufficiently low potential on the central system of the apparatus so as to insure that the instrument worked in conformity with the theory. In order to insure that, under these circumstances, the electroscope-deflection corresponded to the most sensitive portion of its scale, an electroscope was employed of the type provided with a subsidiary insulated case, which could be raised to any desired potential.[3]

[2] *Proc. R. Soc.* A., v. 85, p. 182, 1911.

[3] See C. W. Hewlett, *Terr. Mag.*, v. 19, p. 228, September, 1914.

The apparatus was turned in such a direction that the wind blew through it. The advantage of this is to insure that the air which has passed through the apparatus and which has been largely deprived of its ions shall not be blown back and be caused to enter the funnel again. In order to obtain values of the positive and negative conductivities (λ_+ and λ_-), which were as comparable with each other as possible, a value of λ_- was first determined, then a value of λ_+, and finally another value of λ_-. The mean of the two values of λ_- was then taken as the value of λ_- corresponding to the value measured for λ_+. The expression used for the calculation of the conductivity is

$$\left(4\pi\lambda\frac{C}{C_1}+a\right)T=\log\frac{V_0}{V}$$

where C_1 is the capacity of the whole apparatus, C is the capacity of the portion exposed to the air current,[4] V_0 is the initial potential to which the central system was charged, V the final potential, T the time, and a is a quantity concerned with the leak of the apparatus. The quantity a is equal to the value of $-\dfrac{1}{V}\dfrac{dV}{dt}$ as measured with the ends of the funnel closed, so that no air passes through.

In order to give an idea of the consistency of the readings and of the actual fluctuations of the conductivity, the following typical set of numbers may be cited, which gives a digest of the complete set of observations for the determination of the two values of λ_- and th value of λ_+ corresponding thereto. The table will be self-explanatory when it is remarked that in the case of the first group of six observations, for example, the numbers in the column headed "difference of log's" represent successively the difference of the logarithms of the first and fourth values of V, the second and fifth values, and so on. It is worthy of notice that while the observations for any one determination of λ_- agree very well among themselves, indicating that there is nothing erratic in the behavior of the apparatus, the two sets of observations for λ_-, separated by a period of about half an hour, are systematically different. The kind of difference shown in this table is typical of what was usually found, and emphasizes the importance of measuring all the atmospheric-electric elements as far as possible at the same time if they are to be considered as comparable.

[4] See W. F. G. Swann, *Terr. Mag.*, v. 19, p. 86, June, 1914.

Table 1.

Value of $a = 1.4 \times 10^{-5}$. Date: June 22, 1914.

Sign of ions	Ship's time	V	Difference of log's	λ (E. S. U. $\times 10^{-4}$)
	h m			
Negative.....	11 18	53.1		
	19	50.0		
	20	47.8		
	23	39.0	0.134	
	24	37.0	0.131	
	25	34.6	0.140	
		Mean....	0.135	1.22
Positive......	11 27	60.8		
	28	57.4		
	29	54.4		
	30	50.6		
	31	47.0		
	32	43.3	0.148	
	33	40.7	0.149	
	34	38.0	0.156	
	35	35.5	0.154	
	36	33.5	0.147	
		Mean....	0.151	1.37
Negative.....	11 45	61.6		
	46	58.5		
	47	55.8		
	50	47.9	0.110	
	51	44.7	0.117	
	52	42.2	0.122	
		Mean....	0.116	1.04

Mean value of $\lambda_- = 1.13 \times 10^{-4}$ E. S. U.

Mean value of $\lambda_+ = 1.37 \times 10^{-4}$ E. S. U.

The Ionic Numbers. Only a few observations of the ionic numbers were made, and these were in Gardiner's Bay and Long Island Sound. They were taken simultaneously with the conductivity, and the author's new form of ion counter was employed.[5] The greatly increased sensitivity attained by this apparatus over that of the older form was well brought out by the way in which the fluctuations in the conductivity were accompanied by corresponding ones in the ionic numbers, as measured simultaneously.

[5] *Terr. Mag.*, v. 19, p. 171, September, 1914.

In illustration of this point, the accompanying curve, Fig. 2, shows relative values of the conductivity and of the ionic numbers, measured over a period of thirteen minutes. An exact correspondence of course cannot be expected, as the relation between the ionic numbers and the conductivity involves a variable factor in the specific velocity of the ions. The general correspondence between the two must, however, be considered as satisfactory, since it brings out the fact that the apparatus is sufficiently sensitive and reliable to show fluctuations in the ionic numbers over as short a period as that of a minute or two, whereas with the old form of Ebert apparatus about half an hour or more was necessary in order to obtain a single satisfactory reading of the mean ionic density.[6]

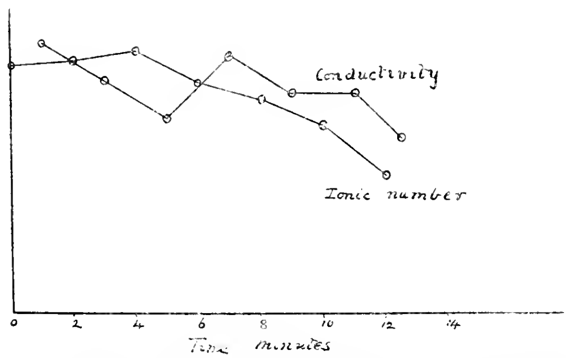

FIG. 2. *Relative Values of Conductivity and of Ionic Numbers.*

From the ionic densities and simultaneously-measured conductivities, the specific velocities of the ions could be calculated, since n and λ are related by the expression $\lambda = nev$, e being the electronic charge.

The Radioactive Content. This element was measured by the stretched wire method of Elster and Geitel with certain modifications suggested by the author in a former communication.[5] It will be remembered that, in the Elster and Geitel method, a wire stretched between two insulators is charged to a potential of $-2{,}500$ volts and allowed to collect the active deposit for a period of two hours, after which it is wound on a frame which is placed in an ionization chamber, the rate of discharge of the electroscope associated with the chamber being afterwards measured at various intervals over a period of an hour or so. In the original experiments

[6] See G. C. Simpson, *Proc. Roy. Soc.*, A., v. 85, p. 188, 1911.

of Elster and Geitel the activity was defined as unity when one meter of the wire caused the electroscope to fall one volt in one hour. In the first place, it is obvious that the unit so defined is a function of the electrical capacity of the ionizing chamber. In the second place, the ambiguity involved in defining the unit in terms of the fall in volts in one hour has led some observers to measure the actual fall in one hour and others to measure the fall of potential per hour at the initial instant. The two quantities are, of course, quite different, since the curve is not a linear one. Again, in so far as theory shows that the amount of active material collected is proportional to the charge on the wire, and since the charge on a wire raised to a given potential is by no means proportional to the length, there is considerable ambiguity in the meaning to be attached to the effect per meter of wire unless we always deal with a wire of the same length. There seems to have been an astonishing amount of vagueness as to the theory of the action of the Elster and Geitel method. According to the theory worked out by the author for a charged conductor exposed to the atmosphere,[7] the number of particles (charged with the sign opposite to that of the conductor) coming to the conductor per second is

$$\frac{\delta N}{\delta t} = 4\pi Q n v \tag{1}$$

where Q is the charge on the conductor, n is the number of the charged particles per c. c. in the air, and v is their specific velocity. The amount of active material collected in a given time is thus (1) proportional to the charge on the conductor and (2) independent of the velocity of the wind, so that the volume of air supplying active material to the conductor per second is independent of the velocity of the wind. In the case of a body like a uniformly-charged wire, it consequently follows that the so-called "collecting distance" of the wire is inversely proportional to the velocity of the wind, and is meaningless unless this velocity is stated. Elster and Geitel appear to have originally assumed that the active material collected was independent of the potential of the wire instead of proportional to it.

As pointed out in the author's former paper,[8] moreover, the potential difference between the wire and the Earth is not the sole

[7] *Terr. Mag.*, v. 19, p. 81, June, 1914; also *Terr. Mag.*, v. 19, p. 216, December, 1914. The particular case of a uniformly charged wire has also been treated in a joint paper by S. Kinoshita, S. Nishikawa, and S. Ono (*Tokyo Sugaku-Buturigakkwai. Kizi*, S. 2, v. 6, No. 6, 1911).

[8] *Terr. Mag.*, v. 19, p. 177, September, 1914.

criterion which determines the charge on the wire when a potential-gradient exists. From a neglect of this consideration, it would appear that in some cases observers must have collected two or three times the amount of active material which they should have collected if precautions had been taken to avoid this effect.

Kurz has made an investigation of certain matters relating to the Elster and Geitel method.[9] Kurz used vertical wires in his experiments. He refers qualitatively to an effect of the atmospheric potential-gradient in disturbing the field around the wire, but he does not appear to have realized the importance of this effect on the absolute value of the activity and, moreover, the simplicity of its theory. It is, in fact, obvious that if a conductor of any shape is placed in the Earth's field, which, to fix our ideas, we shall suppose to be uniform and vertical; and if, as a whole, the conductor has no charge, there will be for a potential-gradient of the normal sign, a positive charge on the lower portion and a negative charge on the upper portion. There will be, furthermore, some plane parallel to the Earth's surface where the charge density is zero.[10] Under these conditions, the potential of the body will be that due to the potential-gradient alone on this plane, say W. If now the body is to be brought to zero potential, it must be given a charge KW, where K is its capacity; and it is worth while noticing that in this case the sign of the charge on every portion of the body will be negative. It consequently will be obvious that, as far as the total charge on the body is concerned, if we raise the potential of the body in a negative sense to a potential V above that of the Earth, the total charge on it will be the same as if it had been raised to a potential $W + V$ and there had been no potential-gradient. In the case of a body symmetrical about a horizontal plane, W is, of course, the potential due to the Earth's field at the plane of symmetry.

For a wire horizontally suspended at a height of 20 meters, and for a potential-gradient of 100 volts per meter, W becomes 2,000 volts; i. e., it is actually about as large as the potential artificially applied to the wire.

[9] K. Kurz, *Abh. Ak. Wiss. Math. phys. Kl.*, Bd. 25, Abh. 1, München, 1909.

[10] Such points must be on a plane, for a little consideration will show that a point on the body where there is no charge must be a point at which the portion of the potential *due to the distribution of charge on the body* is zero. It then follows that all such points lie on a plane for the following reason. The potential at all these points is simply the contribution by the external Earth's field; further, the potential at all the points must be the same because they are on a conductor, and this necessitates that they shall lie on a horizontal plane, since the potential due to the Earth's field is only constant on horizontal planes.

Now, although Kurz has not referred to the magnitude of the influence of the potential-gradient on the measured value of the activity, his experiments show the phenomenon very clearly. He has made experiments to find the relation between the activity and the potential applied to the wire, and the curve, Fig. 3, is drawn from his results, the abscissæ representing the potentials applied to the wire. His wires were vertical, and the top end was 23 meters above the ground. For potentials above 1,000 volts (negative) we see that the curve is practically a straight line; and if we produce it backwards, it cuts the potential axis at 800 volts below zero. This is what we should expect, and shows that to the measured

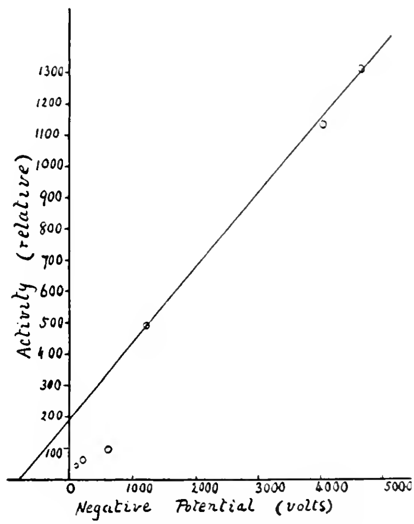

FIG. 3. *Relation between Activity and Potential.*

applied potential something ought to be added, on account of this effect of the potential-gradient. The irregularity of the points on the curve for low potentials is probably to be attributed largely to the fact that the omitted quantity W is in this case so large compared with the other applied potential as to entirely mask it, and in so far as W fluctuates considerably from experiment to experiment, the points are quite irregular. It is curious, however, that they all lie on the same side of the straight line.

The above curve is further interesting as indicating that, if account is taken of this effect of the potential-gradient, the activity is really proportional to the corrected potential (and consequently

to the net total charge on the body), as required by the theory referred to above.

Were it not for the fact that the wires in Kurz's experiments hung only six meters or so from the building, it would be interesting actually to calculate the value of W. The value of W in this case would amount to $\frac{23}{2} \times 100 = 1{,}150$ volts for a potential-gradient of 100 volts per meter.

In an endeavor to render the Elster and Geitel unit a means of determining the actual amount of emanation in the air, or rather what is more important, the saturation current per c. c. which could be produced by the emanation in the air, Kurz, in the paper above referred to, has made simultaneous measurements of the radioactive content of the air by the Elster and Geitel method and by an absolute method. He finds that for an activity of unity as expressed in Elster and Geitel units, the active content of the atmosphere is such as to produce a saturation current per c. c. of 0.55×10^{-4} E. S. U per sq. cm., and consequently a rate of ionization of molecules into ions of amount q, given by

$$qe = 0.55 \times 10^{-11},$$

e being the electronic charge. Thus $q = 0.0114$ is the number of molecules broken up per c. c. per second for an activity[11] $A = 1$.

It is, of course, obvious that, in so far as the relation between the active material on the wire and the active material in the air involves the specific velocities of the carriers, a quantity which is liable to vary greatly from day to day, anything like an accurate relation between A and q is out of the question. Further, apart from this, the relation between A and q can only be considered to have a definite meaning, if the same radioactive constituents are always present in the same proportions.

The latter part of the present report is devoted to an analysis of certain of the activity curves obtained, and it is further shown, for example in the case of the deposits from radium emanation, how, if we knew the specific velocities of the carriers, we could pass from the activity curve to the actual amount of emanation in the atmosphere without making use of the experimental results of Kurz. For the present, however, we shall work on the lines of

[11] In the experiments of Kurz, it is probable that the measured saturation current did not include an appreciable proportion of the effects due to the β and γ rays from the deposit. The whole effect from these sources, however, probably only amounts to about 6 per cent of the effect due to the α rays. We shall consequently neglect consideration of the effects of the β and γ rays.

calculating the rate of production of ions to be accounted for by a given value of the activity, making use of the relation obtained by Kurz. In doing this we shall, however, attend to two points further.

The potential applied to the wire in Kurz's experiments was 2,500 volts. According to the discussion given on page 21, the effective potential in Kurz's experiments was really 2,500 + 800 = 3,300 volts, so that on this account his results for q must be multiplied by $\frac{25}{33} = 0.76$, in order to reduce them for comparison with those obtained on the present cruise, which have all been reduced to a potential of 2,500 volts. Again, the length l of Kurz's wire was 23.5 meters, and the radius a was 0.1 mm., while in the present work the length of the wire was 5 meters and the radius 0.25 mm. In so far as the capacity is proportional to $\frac{l}{2 \log l/a}$, and the activity collected for a given potential is proportional to the capacity, we see that in order to render the results of Kurz for the activity per meter of wire, comparable with the present ones, it is necessary further to multiply his results by $\log \frac{2350}{0.01} / \log \frac{500}{0.025} = 1.25$. Thus the total correcting factor to be applied to Kurz's results is $1.25 \times 0.76 = 0.95$. The fact that the two corrections almost cancel is, of course, accidental. Each of them is large in itself. We thus find that for an activity $A = 1$ we have $q = 0.0108$.

In the tables on pages 46-48, instead of recording the activity A in Elster and Geitel units, a quantity η, of a more fundamental nature, has been recorded; η represents the total rate of ionization of molecules in the ionization chamber corresponding to the active deposit collected by unit charge on the collecting wire. Thus, for example, if V is the effective potential to which the wire was charged during exposure, K its capacity, $\frac{dU}{dt}$ the rate of fall of potential in the ionization chamber at the particular instant under consideration, we have $\eta = \frac{kdU}{KVedt}$, k being the capacity of the ionization chamber and e the electronic charge. The relation between η and A is given by $A = 1.78 \times 10^{-3}\eta$ for the apparatus employed. Allowance is made in this relation for the difference between the capacities of the ionization chamber and that used by Elster and Geitel by multiplying the value of A obtained, neglecting this consideration, by the ratio of the former capacity to the latter.

DISCUSSION OF THE RESULTS.

The observations for the three sections of the cruise are given in tables Nos. 10, 11, 12, a fourth table, No. 13, being devoted to the observations in Gardiner's Bay and Long Island Sound. The average value of the conductivity from New York to Hammerfest is 2.09×10^{-4} E. S. U., from Hammerfest to Iceland the value is 2.69×10^{-4}, and from Iceland to Greenport 2.77×10^{-4}. The average value of the conductivity as measured on land is about 2×10^{-4} E. S. U., so that the sea values are, if anything, greater than those found on land. They are in agreement with results obtained on former cruises of the *Carnegie*. The observations were taken in about every case between the hours of 9 A. M. and 12 noon.

In some cases, the conductivity appears to undergo an interesting change as one passes from the American shore out into the open sea. The conductivity starts considerably below its normal value, but increases again as one gets out into the open sea. This phenomenon may be seen by glancing at the observations of July 11-16, Table 10, when the yacht was departing from the coast, and those of October 5-10, Table 12, as she was nearing the coast. That this effect is due partly to a low value of the specific velocities in the neighborhood of the coast is borne out by the observations in Long Island Sound, where both the conductivity and the ionic numbers were measured, so that the specific velocities of the ions could be computed. Table No. 13 shows the results. The mean values for v_+ and v_- are, at any rate on October 19 and October 21, smaller than those generally assigned as the normal value; values ranging from about 0.8 to about 1.8 cm/sec. per volt per cm. represent the kind of specific velocities usually found in land measurements. The abnormally low values for the conductivity in Long Island Sound are not peculiar to the present observations, as the same phenomenon has been noticed by Observer E. Kidson during the first cruise of the *Carnegie*.[12]

Annual Variation. In Table 2 the atmospheric-electric elements are grouped according to the season of the year. The observations for the two days immediately after leaving New York and for the two days immediately prior to arrival at New York have been omitted on account of the abnormal values of the conductivity referred to above. It may be mentioned, however, that the inclusion of the values for these days would not affect the general conclusions.

[12] *Terr. Mag.*, v. 15, p. 83, 1910.

TABLE [illegible].

Period 1914	$\lambda_+ + \lambda_-$ (E.S.U. $\times 10^{-4}$)	$\frac{\lambda_+}{\lambda_-}$	Pot.-grad. (volts/meter)	Earth-air current (E.S.U. $\times 10^{-7}$)	$\eta \times 10^{-2}$
June 13–June 23	2.24	1.21	75	5.6	62
June 23–June 30	2.43	1.12	90	6.8	109
July 27–Aug. 11	2.38	1.21	79	5.3	89
Aug. 12–Aug. 2[illegible]	2.99	1.25	104	10.5	65
Sept. 15–Sept. 28	3.35	1.19	103	11.5	166
Sept. 29–Oct. 7	2.59	1.22	112	8.1	306

It will be observed that the conductivity shows a marked increase from June to the middle of September, with the exception of the observations for July 27 to August 11, which, however, were rather erratic. This is in accordance with Simpson's observations on the ionic content made in Lapland.[13] Simpson found a minimum for the ionic content at the end of February and a maximum at the end of August. It is not in accord with the observations at Potsdam, however, which show both in the daily means and also in the values taken between 9 A. M. and 12 noon a decrease from June to September. It must be remarked, however, that the average latitude for the present observations is higher than that of Potsdam. It is possible that the difference is to be attributed to an effect on the specific velocities of the carriers. If the specific velocities were constant throughout the year, the conductivity curve should follow the ionization curve. The agreement of the present observations with Simpson's ionization curve would seem to indicate that the specific velocities at sea are not subject to much annual variation, or at any rate to such an annual variation as would materially affect the relationship between the annual variations of the conductivity and ionic numbers. The disagreement of the present observations with those at Potsdam, unless it is to be attributed totally to an effect of latitude, would therefore indicate that the specific velocities of the ions are affected more by seasonal changes over land than over the sea.

The quantity $\frac{\lambda_+}{\lambda_-}$ indicates a fairly definite minimum in the neighborhood of July to August. It is probable that one of the

[13] *Phil. Trans.*, S. A., v. 205, p. 61, 1905.

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causes which participates in making $\frac{\lambda_+}{\lambda_-}$ greater than unity is the fact that the effect of water vapor, dust, etc., is greater on v_- than on v_+. It may be that the minimum shown for $\frac{\lambda_+}{\lambda_-}$ in Table 2 is not a true seasonal phenomenon, but is simply due to the fact that the atmosphere in the arctic regions is especially clear, and from June to July the ship was approaching the arctic regions, while during the latter portion of the cruise she was leaving them. It must be observed that Simpson, in the paper already referred to, finds in Lapland a minimum for $\frac{n_+}{n_-}$ about June.

The seasonal variation of the potential-gradient is not very marked, but in a general way this element shows an increase from summer to winter which is in accordance with land observations.

The Earth-air current follows the general course of the conductivity, but little information can be drawn with regard to the variation of the active content. The numbers, however, are not inconsistent with Simpson's results in Lapland, showing that the deposit is high in winter and low in summer.

It has been thought worth while to arrange the observations according to latitude, and this is done in Table 3, the mean value being taken for ranges of latitude in each limb of the voyage. As far as the numbers in Table 3 go, there seems to be an indication of the conductivity and Earth-air current showing a maximum in

Table 3. (*Arrangement According to Latitude.*)

Lat. North	Limb of cruise	No. of Obs'ns[14]	$\lambda_+ + \lambda_-$ (E.S.U. $\times 10^{-4}$)	Pot.-grad. (volts/meter)	Earth-air current (E.S.U. + 10^{-7})	$\eta \times 10^{-2}$
° °						
40–45	New York to Hammerfest.	4	1.74	70	4.3	74
	Iceland to Greenport.....	5	2.25	142	8.4	351
	Mean..............		2.00	106	6.3	212
45–51	New York to Hammerfest.	3	2.90	64	7.3	38
	Iceland to Greenport.....	5	3.19	83	9.4	126
	Mean..............		3.04	73	8.3	82
51–57	New York to Hammerfest.	3	2.42	72	5.7	133
	Iceland to Greenport.....	3	3.05	82	8.2	239
	Mean..............		2.74	77	7.0	186
57–68	New York to Hammerfest.	4	2.44	104	7.8	85
63–68	Hammerfest to Iceland...	6	2.89	99	9.6	66
57–61	Iceland to Greenport.....	5	3.47	113	12.9	93
	Mean..............		2.93	105	10.1	81
68–75	Hammerfest to Iceland...	5	2.52	97	7.8	80
75–78	Hammerfest to Iceland...	3	2.56	61	4.9	100

[14] The figures refer to the number of conductivity observations.

the neighborhood of 50°; but in view of the small numbers of observations from which it has been necessary to strike each mean, and of the variation in those observations, we can hardly do more than take this maximum as an indication of something to be looked out for in future observations. It may be mentioned that in a general way the seasonal changes are more or less eliminated in Table 3, since almost for each range of latitude there are observations corresponding to the outward and return journeys.

Simpson[15] found an increase of radioactive content with decrease of latitude from 40° to 10°, but between 10° and 0° the activity was small. The explanation given by Simpson and Wright of this phenomenon involves consideration of the effect of the air which descends in the high pressure belt between latitudes 30° and 40°, and which travel toward the equator, so that since the observations are all confined to latitudes above 40°, this theory is not applicable to them.

In Table 4 the atmospheric elements are arranged according to the relative humidity. The observations were divided into various groups according to the relative humidity, and the mean value of the elements for each group have been recorded beside the mean relative humidity for the group.

TABLE 4.

No. of obs'ns	Relative humidity	$\lambda_+ + \lambda_-$ (E. S. U. $\times 10^{-4}$)	$\frac{\lambda_+}{\lambda_-}$	Pot.-grad. (volts/meter)	Earth-air current (E. S. U. $\times 10^{-7}$)	$\eta \times 10^{-2}$
7	86	2.68	1.17	87	7.5	193
9	91	2.87	1.18	91	8.5	197
15	95	2.58	1.25	88	7.4	113
14	98	2.53	1.11	100	8.6	89

None of the atmospheric-electric elements appear to show any marked variation with the relative humidity, though there is some indication of a decrease of the conductivity and increase of the potential-gradient with increase of humidity.[16] Hewlett, on the second cruise of the *Carnegie*, found that the conductivities, averaged for the whole cruise, showed a marked relation to the relative humidity, the conductivity decreasing with increase of relative humidity.

[15] G. C. Simpson and C. S. Wright, *Proc. Roy. Soc.*, A., v. 85, 1911.

[16] *Terr. Mag.*, v. 19, p. 143, September, 1914.

TABLE 5.

No. of obs'ns	Temp. (cent.)	Relative humidity	$\lambda_+ + \lambda_-$ (E.S.U. $\times 10^{-4}$)	$\frac{\lambda_+}{\lambda_-}$	Pot.-grad. (volts/meter)	Earth-air current (E.S.U. $\times 10^{-7}$)	$\eta \times 10^{-2}$
19	6.0	94	3.04	1.21	84	8.7	127
10	8.0	95	2.75	1.20	99	9.1	118
10	11.0	94	2.76	1.17	91	8.7	68
9	16.0	93	2.13	1.22	94	6.2	184

In Table 5 the atmospheric-electric elements are grouped according to the temperature. Here again no marked variation of any of the elements is shown, which is somewhat contrary to what has usually been found on land. On land the ionization shows a marked increase with rise in temperature. It must be observed, however, that the conductivity involves both the specific velocities and the ionic numbers, and since the specific velocities are liable to variations due to many causes, the behavior of the conductivity is likely to be more complex than that of the ionic numbers.

The variations of the atmospheric-electric elements with the meteorological data, etc., are liable to be rendered complex because they are measured near the Earth's surface, i. e., in a region where the former quantities are so dependent on each other. For example, as pointed out by the author in a former communication,[17] for a typical case the potential-gradient would, in a quiescent atmosphere, cause the positive and negative ions at a height of 3.5 meters to have, respectively, only 0.85 and 0.4 times the normal value which they would have in the absence of a potential-gradient under the condition of equilibrium between recombination and formation. For smaller heights the discrepancy would be worse, and it is a function of the potential-gradient, specific velocity of the ions, coefficient of recombination, and rate of formation of ions.

It is natural to expect a smaller radioactive content in the case of air which has passed for some time over the ocean than in the case of air which has passed recently over land. An examination of the tables 10 to 12 in conjunction with the map (Fig. 1) of the cruise enables us to form an idea as to whether the winds are such as have blown for some time over sea or land. At the feet of the tables the general nature of the wind in this respect is given. Taking the voyage from New York to Hammerfest, we see that with one exception (that of June 19) the winds which have been classed as

[17] W. F. G. Swann, *Terr. Mag.*, v. 18, p. 179, December, 1913.

having blown off land correspond to the highest values of the radioactive content.

No very definite conclusion in this respect emerges from a consideration of the results of the voyage from Hammerfest to Iceland, but the winds on the voyage were usually of very small velocity, and it is consequently difficult to form much idea as to the probable course which the air had pursued in the days preceding any given one for which the strength is recorded. In the voyage from Iceland to Greenport the conclusion is borne out, except in the case of some of the observations from October 5 onwards; the winds in these observations, however, were comparatively light. As a rule we find the greatest certainty in the interpretation of the results when the winds are strong, which is what might be expected.

With regard to the actual relationship between the radioactive-content and the conductivity produced, this has been calculated as stated above, making use of Kurz's reduction of the Elster and Geitel unit to absolute measure. Table 6 represents the results, the mean value of $\lambda_+ + \lambda_-$ being taken for each limb of the cruise in the calculated value. In the table, the value of the number of ions per c. c. of either sign has been calculated from the expression $n^2 = q/\alpha$, where α is the coefficient of recombination of the ions and is taken as 1.56×10^{-6}. The conductivity is taken as $2nev$, v being the specific velocity of the ions. The value of v has been taken as 1.6 cms. per second per volt per cm. for each sign of ions.

In the observations in Long Island Sound n was measured directly for each kind of ion, and so it became possible there to

TABLE 6.

Limb of cruise	A	q	$n_+ + n_-$		$\lambda_+ + \lambda_-$	
			Observed	Calculated	Observed (E.S.U. · 10^{-4})	Calculated (E.S.U. · 10^{-4})
New York to Hammerfest	14.8	0.160	...	...	2.09	1.47
Hammerfest to Iceland	13.9	0.150	...		2.69	1.43
Iceland to Greenport	39.9	0.43	..	.	2.77	2.42
Long Island Sound, Oct. 19	59.5	0.64	923	1280		
Long Island Sound, Oct. 21	39.0	0.42	434	1040		

compare the measured value of $n_+ + n_-$ with the calculated $2n$ without introducing the specific velocity of the ions.

In the above calculated values the effect of the penetrating radia-

tion from the active material in the sea has been neglected. This effect is very small, however.[18]

It will be seen that while in the Atlantic Ocean the radioactive material is sufficient to account for an appreciable fraction of the conductivity, it is by no means sufficient to account for all of it. It must further be borne in mind that in so far as many of the ions produced by the radioactive material in the air undoubtedly go into the type of the slowly moving Langevin ions, the calculated conductivity should be even smaller. Again, apart from this, the calculated conductivity gives the values which would be true if the ions in the atmosphere near the Earth's surface were maintained at the value given by the relation $q = \alpha n^2$. In practice, the potential-gradient causes the number of both the positive and negative ions to be lower than their normal value, the effect being greater in the case of the negative than in the positive ions. On this account, also, the calculated values of n and λ should consequently be reduced. It is possibly for these reasons that the calculated values in the case of the observations in Long Island Sound came out even greater than the measured values. The average value of the emanation content during the whole cruise (omitting the Long Island Sound observations) corresponds to an activity expressed in Elster and Geitel units of 23, and is such as to correspond to a rate of production of 0.24 ions per c. c. per second. 10^{-12} curie of radium emanation per cubic meter corresponds to the production of 0.020 ions per c. c. per second, hence the average radium emanation content amounts to about 12×10^{-18} curies per c. c., as against 80×10^{-18} curies per c. c., which is about the average value for the land.

On the Determination of the Nature of the Active Material in the Atmosphere.

As is well known, the activity of the deposit collected on the wire in the Elster and Geitel method usually decays to half value in about 45 minutes. With the object of determining the nature of the radioactive constituents in the atmosphere, Bumstead[19] exposed a charge wire to radium emanation contained in a two liter flask, and compared the decay curves obtained in this case with those obtained for the wire exposed to the atmosphere. The curves were in sufficiently good agreement to satisfy him that radium

[18] A. S. Eve, *Phil. Mag.*, S. 6, v. 21, p. 36, 1911.

[19] *Am. Jour. Sci.*, S. 4., v. 18, p. 1, 1904.

emanation was the main radioactive constituent of the atmosphere. By taking longer exposures of the wire to the atmosphere, Bumstead was also able to make the presence of thorium evident, but this fact does not concern us for the present. The point to which it is desired to call attention is this. When a charged wire is exposed to emanation in a closed vessel of small size, the charged active particles are carried to the wire as fast as they are formed. Neither the specific velocities of the carriers nor the amounts per c. c. of the emanation products in the air are involved. In the case of radium emanation, for example, after the products initially present are cleared out, the radium A is deposited as fast as it is formed from the emanation, and nothing but radium A is deposited. Now, when the wire is exposed to the atmosphere, it turns out, as pointed out on page 19, that if Q is the charge on the wire, n the number of carriers per c. c. of any particular kind in the atmosphere, and v their specific velocity, the rate of supply of the carriers to the wire is $\frac{\delta N}{\delta t} = 4\pi Q n v$. Thus each carrier present is deposited, and at a rate proportional to the amount of the carrier present and to its specific velocity. The resulting decay curve of the deposit on the wire will consequently be different to what it would be if only radium A had been deposited, in spite of the fact that the radium A breaks up on the wire. For this reason, and because, as one might expect from the above argument, the decay curves obtained during the cruise are not all of the same form, and do not all show the same half-period interval, it has been thought worth while to attack, by another method, the problem of determining whether the decay curve corresponds to radium emanation. A knowledge of the specific velocities of the carriers would enable us to go further and determine the actual amount of radioactive material in the atmosphere. It turns out, however, that in order to calculate by this method amounts which are in anything like agreement with those found by assuming the empirical relation of Kurz, it is necessary to assume that the average value of the specific velocities of the carriers are very much smaller than is generally supposed.

In so far as the effect of the radium emanation is concerned, we need only consider the effects of deposition on the wire of radium A, B, and C (looking upon C as a single substance). The rates of formation of D, E, and F are so slow that even if there were no air motion it is obvious that the potential-gradient itself

would clear the atmosphere of these products as fast as they were formed, bringing down to Earth those which were positively charged. We shall then examine the consequences of looking upon the deposit on the wire as consisting of radium A, B, and C. The constants of decay of radium A, B, and C are $\lambda_A = 3.85 \times 10^{-3}$, $\lambda_B = 4.33 \times 10^{-4}$, and $\lambda_C = 5.93 \times 10^{-4}$. Radium B emits no α rays, but, though little ionization is caused by β and γ rays, the radium B nevertheless plays a part in the phenomenon by contributing to the supply of radium C. We shall only take account of the ionization produced by the α particles in the ionization chamber, an assumption which is approximately true, especially in view of the comparatively small dimensions of the latter.

The radium A on the wire is there entirely as the result of direct deposition from the atmosphere. Of the radium B on the wire, part is there as the result of direct deposition and part as the result of the disintegration of the radium A deposited on the wire. Of the radium C on the wire, part is there as the result of direct deposition, part as the result of the disintegration of the radium B which was *deposited*, and part as the result of the disintegration of the radium B which was formed by disintegration from radium A. We shall find it convenient to separate these parts in our mind's eye.

Suppose T is the time of exposure of the wire to the atmosphere.

Let n_A = number of particles of radium A *deposited* per second during period T.

Let n_B = number of particles of radium B *deposited* per second during period T.

Let n_C = number of particles of radium C *deposited* per second during period T.

Let t be the time at any instant after the wire ceases to be exposed to the atmosphere, the time $t = 0$ being the instant when the exposed wire was discharged.

Let N_A = number of particles of radium A on wire at time t due to deposition.

Let N_B = number of particles of radium B on wire at time t due to deposition.

Let N_C = number of particles of radium C on wire at time t due to deposition.

Let $\overline{N}_B$ = number of particles of radium B on wire at time t due to their formation on the wire from radium A.

Let $\overline{N}_C$ = number of particles of radium C on wire at time t due to their formation on the wire from radium A via radium B.

Let $\overline{\overline{N}}_C$ = number of particles of radium C on wire at time t due to formation from the radium B deposited.

Now, in Rutherford's "Radioactivity" (second edition), page 335, the following problem is solved:

"Suppose that a primary source has supplied the matter A at a constant rate for any time T, and is then suddenly removed; required the amount of A, B, and C at any subsequent time." If P, Q, and R represent the respective amounts; λ_1, λ_2, and λ_3 the constants of change, and n_0 the rate of supply of the matter A, it is shown that

$$P = \frac{n_0}{\lambda_1}\left(1 - e^{-\lambda_1 T}\right) e^{-\lambda_1 t} \tag{2}$$

$$Q = Q_T \frac{a\, e^{-\lambda_2 t} - b\, e^{-\lambda_1 t}}{a - b} \tag{3}$$

$$\text{where } a = \frac{1 - e^{-\lambda_2 T}}{\lambda_2} \qquad b = \frac{1 - e^{-\lambda_1 T}}{\lambda_1} \tag{4}$$

$$\text{and } Q_T = \frac{n_0 \lambda_1}{\lambda_1 - \lambda_2} \int_0^T \left(e^{-\lambda_2 t} - e^{-\lambda_1 t}\right) dt$$

$$= \frac{n_0 \lambda_1}{\lambda_1 - \lambda_2} \left\{ \frac{1 - e^{-\lambda_2 T}}{\lambda_2} - \frac{1 - e^{-\lambda_1 T}}{\lambda_1} \right\} \tag{5}$$

The expression for R we shall not require.

The above expression takes into account the decay of the products which goes on between their deposition on the wire and the time of discharge of the wire, and so applies even to a case where a steady state has not been attained. Applying the above first to the case of the radium A deposited at the rate n_A particles per second, we see that from (2)

$$\lambda_A N_A = n_A \left(1 - e^{-\lambda_A T}\right) e^{-\lambda_A t} \tag{6}$$

$$\text{Similarly} \quad \lambda_B N_B = n_B \left(1 - e^{-\lambda_B T}\right) e^{-\lambda_B t} \tag{7}$$

$$\text{and} \quad \lambda_C N_C = n_C \left(1 - e^{-\lambda_C T}\right) e^{-\lambda_C t} \tag{8}$$

Since the rate of decay of radium A is so great, we may assume that very soon after the commencement of the deposition the rate of production of radium B from the radium A already deposited is the same as the rate of deposition of radium A, so that again applying (2) we have $\lambda_B \overline{N}_B = n_A \left(1 - e^{-\lambda_B T}\right) e^{-\lambda_B t}$ (9)

To obtain the rate of generation of radium C due to the radium B which is formed from radium A on the wire, and which we are looking upon as supplied at the rate n_A, we thus can use (3) and so obtain

$$\lambda_C \bar{N}_C = \frac{n_A \lambda_B \lambda_C}{\lambda_B - \lambda_C} \left\{ \frac{1 - e^{-\lambda_C T}}{\lambda_C} - \frac{1 - e^{-\lambda_B T}}{\lambda_B} \right\} \left\{ \frac{b\, e^{-\lambda_B t} - a\, e^{-\lambda_C t}}{b - a} \right\} \tag{10}$$

where in this case $a = \dfrac{1 - e^{-\lambda_C T}}{\lambda_C}$; $b = \dfrac{1 - e^{-\lambda_B T}}{\lambda_B}$

$$\text{so that} \quad \lambda_C \bar{N}_C = \frac{n_A \lambda_B \lambda_C}{\lambda_C - \lambda_B} \left\{ b\, e^{-\lambda_B t} - a\, e^{-\lambda_C t} \right\} \tag{11}$$

Similarly for the rate of generation of radium C from the radium B which is deposited at the rate n_B we have

$$\lambda_C \bar{\bar{N}}_C - \frac{n_B \lambda_B \lambda_C}{\lambda_B - \lambda_C} \left\{ b\, e^{-\lambda_B t} - a\, e^{-\lambda_C t} \right\} \tag{12}$$

For an exposure of 2 hours (7,200 seconds) we find

$e^{-\lambda_A T}$ = practically zero. $e^{-\lambda_B T} = 0.045$. $e^{-\lambda_C T} = 0.014$.
$a = 1660$. $b = 2200$.

Putting in these values, we readily find

$$\lambda_A N_A = n_A e^{-\lambda_A t} \tag{13}$$
$$\lambda_B N_B = 0.955\, n_B e^{-\lambda_B t} \tag{14}$$
$$\lambda_C N_C = 0.986\, n_C e^{-\lambda_C t} \tag{15}$$
$$\lambda_C \bar{N}_C = 0.869\, n_A \left\{ 4.07\, e^{-\lambda_B t} - 3.07\, e^{-\lambda_C t} \right\} \tag{16}$$
$$\lambda_C \bar{\bar{N}}_C = 0.869\, n_B \left\{ 4.07\, e^{-\lambda_B t} - 3.07\, e^{-\lambda_C t} \right\} \tag{17}$$

Let p, q, r be the numbers of ions produced by an α particle of radium A, radium B, and radium C respectively. Since an atom of radium A and an atom of radium C in breaking up each emit one α particle, while an atom of radium B emits no α rays in disintegrating, we see that the total rate of production of ions at the time t, due to the deposit on the wire, is composed of three parts, $y_1 + y_2 + y_3$, where

$$y_1 = \lambda_A N_A p + \lambda_B \bar{N}_B (o) + \lambda_C \bar{N}_C r^{\cdot} \tag{18}$$
$$y_2 = \lambda_B N_B (o) + \lambda_C \bar{\bar{N}}_C (r) \tag{19}$$
$$y = \lambda_C N_C r \tag{20}$$

Here y_1 represents the total ionization, in the ionization chamber, due to the radium A *deposited*, together with that due to its products as formed on the wire; y_2 represents the total ionization due to the radium B *deposited* together with that due to its products as formed on the wire; and y_3 represents the total ionization due to the radium C *deposited*, the whole of the α rays being assumed

to be effective in producing ions in each case. Making use of equations (13) to (17), and of the fact that $p = 1.87 \times 10^5$, $r = 2.37 \times 10^5$, we find

$$y_1 = n_A \left\{ 1.87\, e^{-\lambda_A t} + 8.38\, e^{-\lambda_B t} - 6.32\, e^{-\lambda_C t} \right\} \times 10^5 \quad (21)$$

$$y_2 = n_B \left\{ 8.38\, e^{-\lambda_B t} - 6.32\, e^{-\lambda_C t} \right\} \times 10^5 \quad (22)$$

$$y_3 = n_C \left\{ 2.34\, e^{-\lambda_C t} \right\} \times 10^5 \quad (23)$$

The quantity $y_1 + y_2 + y_3$ plotted against t should of course give a curve whose ordinates are proportional to the ordinates of the decay curve of the active deposit in so far as it is due to radium deposits, and it must be our purpose to see whether n_A, n_B, n_C can be chosen so that the decay curve can be built up out of three curves of the types 21, 22, and 23. If this is possible, we may say that the decay curve is capable of being entirely accounted for by radium emanation products. It will be noted that the argument in no way involves the assumption that the products in the atmosphere are in radioactive equilibrium, or that they are deposited in amounts proportional to those in which they are present. Of course, it is necessary to be on one's guard against drawing too rigorous conclusions from the possibility of fitting up the experimental curve from curves of the type y_1, y_2, and y_3, since there is a good deal of latitude in the types of curves which can be constructed with these three curves as basis. It must be remembered, however, that the exponents of e in the expressions for y_1, y_2, and y_3 are here fixed quantities, the only adjustable constants being n_A, n_B, and n_C, which renders the conclusions much more definite than would have been the case if the exponents of e had been adjustable. If the products in the atmosphere were in radioactive equilibrium, and if they were deposited at rates proportional to the number per c. c. present, we should have $\lambda_A n_A = \lambda_B n_B = \lambda_C n_C$. Taking the decay curve for Long Island Sound (October 19), we find that it is necessary to take $\lambda_A n_A$, $\lambda_B n_B$, $\lambda_C n_C$, in the ratio 2 : 2 : 1, in order to build up out of y_1, y_2, and y_3 a curve which is of the same form as the decay curve found experimentally. In this case, however, we obtain a very good agreement, an agreement well within the limits of accuracy of the experiment.

Table 7 shows the values of the ordinates of the decay curve at various times, and also the theoretical values (column 3) built up by assuming $\lambda_A n_A$, $\lambda_B n_B$, $\lambda_C n_C$ in the ratio 2 : 2 : 1 (first hypothesis). In order to show the kind of effect obtained by taking ratios other than these, the fourth column gives the relative values

of η calculated by taking $n_A\lambda_A : n_B\lambda_B : n_C\lambda_C :: 1 : 1 : 1$ (second hypothesis).

Table 7. *Values of $\eta \times 10^{-2}$.*

Time (minutes)	From curve	Calculated (first hypothesis)	Calculated (second hypothesis)
0	334	334	334
2.5	323	319	316
5	310	307	301
10	287	288	277
20	245	251	233
30	210	215	195
40	179	181	161
60	124	123	106
70	102	101	87
80	82	81	69
100	50	53	44
120	30	34	28
140	19	21	17
160	12	13	11

It is interesting to observe at this stage what kind of a curve we should expect if we were to expose the charged wire to radium emanation in a small closed vessel, as in Bumstead's experiment. In this case the active carriers would be deposited as fast as they were formed. There would be an initial clearing out of the active carriers in the vessel, after which the radium A would be deposited as fast as it was formed. The experimental curve in this case would thus correspond very approximately to the type given by y_1 above. Referring to the actual values of λ_A, λ_B, and λ_C, and to equations (21), (22), and (23), we see that the relatively large value of λ_A causes the y_1 curve to fall more abruptly than the y_2 and y_3 curves at first. After a time, however, the term $1.87\ e^{-\lambda_A t}$ becomes insignificant compared with the others, and the y_1 curve approximates to the same shape as the y_2 curve. In view of the fact that λ_C is greater than λ_B, however, the y_2 curve falls less rapidly than the y_3 curve, so that a curve composed of y_2 and y_3 falls more rapidly than a curve composed of y_2 alone, and further, when the time is so great that the term involving λ_A has become negligible, we see that a curve involving y_1, y_2, and y_3 will fall more rapidly than one involving y_1 alone; and, indeed, this conclusion is not limited to large values of the time for the effect of the term involving λ_A is to increase the rate at which the curve falls, so that in no portion of the decay curve can the curve fall more rapidly than a curve of the type y_2. Thus the characteristic difference

between a curve composed of y_1 alone (such as would be obtained by exposure in a closed vessel) and a curve composed of y_1, y_2, and y_3 (such as would be obtained by exposure to the open air) is that initially the former curve falls more rapidly than the latter, but after a time it falls less rapidly than the latter.

Referring again to the expressions for y_1, y_2, and y_3, and recalling, as above explained, that for large values of t the y_2 curve falls more slowly than any combination that can be made out of y_1, y_2, and y_3, we see that if our experimental curve for large values of t

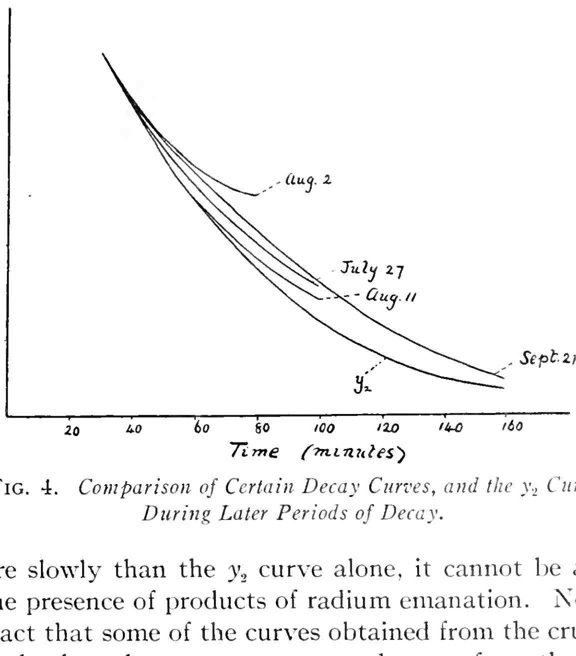


FIG. 4. *Comparison of Certain Decay Curves, and the y_2 Curve, During Later Periods of Decay.*

falls more slowly than the y_2 curve alone, it cannot be accounted for by the presence of products of radium emanation. Now, it is a curious fact that some of the curves obtained from the cruise decay more slowly than the y_2 curves, as may be seen from the following graph, Fig. 4, in which the curves for certain typical days are drawn together with the y_2 curves. In drawing these curves, only the portion of the curve referring to a time greater than 30 minutes after the stopping of the deposition has been drawn, and the scales of the curves have been adapted so that they all start at the same value, at $t = 30$, the object being to bring out the fact above referred to. In many cases the observations of the decay curves were not extended over a sufficiently long time to enable conclusions on this point to be drawn, but a general examination of the curves indicates that near land, and especially near the American Con-

tinent, the decay curve can be accounted for entirely by radium emanation, while the observations taken well out to sea, especially those in northerly latitudes, indicate a slower rate of decay than is possible with the radium curve in the later stages. This conclusion must be put forward rather tentatively, however, for the observations from which the decay curves were plotted often did not fall well on a smooth curve. The observations of August 2 were taken off the coast of Spitzbergen, at about 78.3° N. latitude, those of August 11 were taken at a point in the middle of the ocean, north of Iceland, and about equidistant from Iceland, Greenland, and Norway. The observations of July 27 were taken well out to sea, about halfway between Hammerfest and Spitzbergen. Those of September 21 were taken about 500 miles off the Canadian coast, in the direction of the most southerly part of Greenland. As examples of observations agreeing well with the assumption of radium emanation, we may take that of October 19, taken in Long Island Sound, and already referred to, and the observations of October 3 and August 20, the former being taken near the American coast and the latter about 100 miles east of the coast of Iceland with the wind blowing from the southwest. Fig. 5 shows these three curves plotted so that the degree of consistency of the observations can be judged, and in Table 8 are shown the values of η for various values of t taken from the curves and the values calculated by assuming values of $n_A\lambda_A$, $n_B\lambda_B$, and $n_C\lambda_C$, in the ratios 2 : 2 : 1 for October 19 and October 3, and 0 : 1 : 2 for August 20.

Bumstead came to the conclusion that the decay curves obtained from wire exposed on land were to be attributed to a mixture of radium and thorium emanations. The half periods of thorium emanation, thorium A, thorium B, thorium C, and thorium D, respectively are 54 seconds, 0.14 seconds, 10.6 hours, 60 minutes, and 3.1 minutes. The comparatively slow rate of decay of thorium B results in the activity of the exposed wire increasing appreciably with the time of exposure for a greater length of time than is the case with the deposits for radium emanation. In fact, though the amount of thorium in the atmosphere may be small, its effect can be brought out by a long exposure of the wire to the emanation. The exposure of the wire in the observations taken on the cruise only lasted for two hours, and as a longer exposure than this is desirable for investigating the question of the presence of thorium, it is hardly possible to decide with any certainty as to whether the

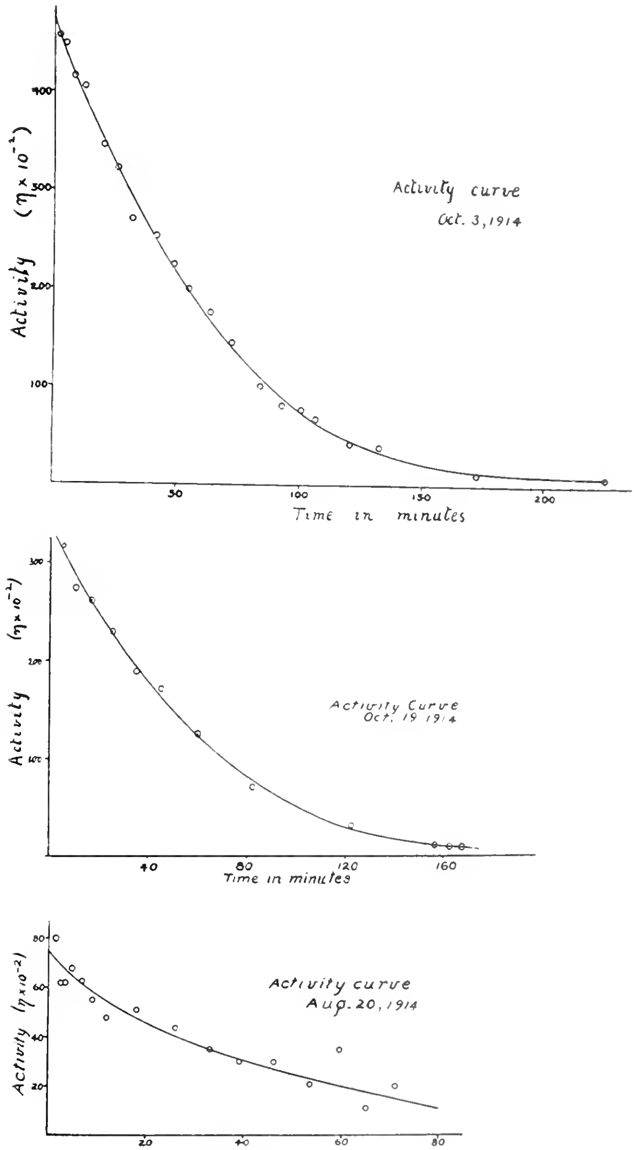


FIG. 5. *Typical Activity Curves.*

Table 8. *Values of $\eta \times 10^{-2}$.*

Time (minutes)	October 19, 1914		October 3, 1914		August 20, 1914	
	From Curve	Calculated	From Curve	Calculated	From Curve	Calculated
0	334	334	475	474	750	751
2.5	323	319	455	453	690	713
5	310	307	440	436	645	676
10	287	288	407	409	570	610
20	245	251	350	355	460	491
30	210	215	297	305	375	394
40	179	181	253	257	305	314
60	124	123	177	173	200	197
70	102	101	145	144	155	157
80	82	81	117	115	120	123
100	50	53	75	75		
120	30	34	45	48		
140	19	21	28	29		
160	12	13	17	18		

slow diminution of the rate of decay in these curves showing this phenomenon is to be attributed to thorium or not.

At first sight, we might think that it would be very improbable that thorium emanation should be found over the sea, since thorium is not contained in appreciable amounts in sea water; and its rate of decay is too small to permit of its traveling far from land, and, indeed, this is true as far as the emanation is concerned. Thorium *A* also has a very short period. Thorium *B*, however, has a half period of about 10.6 hours, and thorium *C*, 1 hour. If these products are positively charged, however, they could not travel very far from land out to sea, for the potential-gradient would clear them out, drawing them down to the Earth's surface, and there would be over the sea no more emanation left to renew the supply. Even if the motion of the air were such as to carry the emanation upwards, it would only be in exceptional cases that the potential-gradient would exactly balance this effect. In spite of these facts, even though the amount of thorium in sea water may be inappreciable, it may be just possible that thorium *B* may be found in the arctic regions for the following reasons. In the equatorial regions and lower latitudes the air rises and passes with probably a very considerable velocity in the higher strata toward the arctic regions, where it descends. Data on the average velocity of a particle of air during such a journey are lacking, but from a general consideration of the known data, it is not inconceivable that such a

particle might leave the Earth's surface at a latitude of say 20° and reach a latitude 80° in a day, or possibly 2 days. The air rising from the land, in the lower latitudes, would contain thorium emanation which would quickly decay, and thorium *B* would finally be formed. This would be carried upwards by the vertical motion of the air in spite of the effect of the potential-gradient pulling it down, which last effect would only amount to a velocity of about 2 cms. per second under ordinary conditions. The thorium *B* would decay during its subsequent journey, but at the end of 1 day there would still be 1/4 of it left, and at the end of 1.5 days about 1/10 of the original amount left. It is a significant fact that the slow rates of decay found at the latter points of the activity curves are found chiefly in those observations taken in higher latitudes.

Absolute Calculation of the Amount of Emanation Present Per C. C.

As an example of how we could deduce the actual amounts of radium *A*, *B*, and *C* in the air if the specific velocities of the carriers were known, we shall consider the curve for October 19. For this curve we have, $\dfrac{n_A \lambda_A}{2} = \dfrac{n_B \lambda_B}{2} = \dfrac{n_C \lambda_C}{1}$

$$\text{Hence } n_B = \frac{\lambda_A}{\lambda_B} n_A \, ; \; n_C = \frac{\lambda_A}{2\lambda_C} n_A$$

Hence the total production of ions per second due to active deposits on the wire is

$$y_1+y_2+y_3=\lambda_A n_A \times 10^5 \left[\left\{ \frac{1.87\, e^{-\lambda_A t} + 8.38\, e^{-\lambda_B t} - 6.32\, e^{-\lambda_C t}}{\lambda_A} \right\} + \frac{1}{\lambda_B} \left\{ 8.38\, e^{-\lambda_B t} - 6.32\, e^{-\lambda_C t} \right\} + \frac{1}{2\lambda_C} \left\{ (2.34)\, e^{-\lambda_C t} \right\} \right]$$

Putting in the values of λ_A, λ_B, and λ_C, we get, at the initial instant, when $t = 0$, $y_1 + y_2 + y_3 = 77.5 \times 10^7 \lambda_A n_A$. Now, using equation (1) and writing v_A for the specific velocity of the radium *A* particles and $\bar{n}_A$ for the number of radium *A* particles present per c. c. in the air, we have[20]

$$n_A = 4\pi Q \bar{n}_A v_A$$

$$\text{Hence} \quad y_1 + y_2 + y_3 = 4\pi Q \lambda_A \bar{n}_A v_A \, (77.5 \times 10^7)$$

[20] Similarly if $\bar{n}_B$ and $\bar{n}_C$ are the numbers of radium *B* and radium *C* particles per c. c. in the air, $n_B = 4\pi Q \bar{n}_B v_B$, and $n_C = 4\pi Q \bar{n}_C v_C$. If the particles in the air are in radioactive equilibrium, $\bar{n}_A \lambda_A = \bar{n}_B \lambda_B = \bar{n}_C \lambda_C$, so that $n_A \lambda_A : n_B \lambda_B : n_C \lambda_C$ should be in the ratio $v_A : v_B : v_C$.

If $\overline{n}_E$ is the number of atoms of radium emanation per c. c. in the air, λ_E the constant of change for radium emanation, and if $\overline{n}_R$ is the number of atoms of radium which would be in equilibrium with the above emanation, and if λ_R is the constant of change for radium

$$\overline{n}_R \lambda_R = \overline{n}_E \lambda_E = \overline{n}_A \lambda_A$$

so that $$y_1 + y_2 + y_3 = 4\pi Q \overline{n}_R \lambda_R v_A \, (77.5 \times 10^7) \qquad (24)$$

Now, the initial value of the quantity η represents the initial rate of production of ions per c. c. in the ionization chamber due to unit charge on the wire, so that if all the α particles had been effective in producing ions, ηQ would be equal to the right-hand side of (24).

Now, half the α particles emitted from the deposit on the wire go into the wire. Again the frame on which the wire is wound very nearly fits the ionization chamber, so that the α particles which are shot out from the wire between the frame and the wall do not have an opportunity of traveling enough of their range to produce an appreciable number of ions. Hence as far as these two phenomena are concerned, we see that $4\eta Q$ is the quantity which should be equated to the right-hand side of (24). Possibly it is unfair to say that no ionization is produced by the particles shot out between the frame and the wall of the ionization chamber, but this is offset by the fact that some of the α particles which are shot inwards, but not perpendicular to the axis of the ionization chamber, strike the bottom and top of the chamber before completing their range. We should thus probably be not far wrong in writing $4\eta Q$ as equal to the righthand side of (24), so that $4\eta = (77.5 \times 10^7)\,(4\pi\, \overline{n}_R \lambda_R v_A)$. Since the atomic weight of radium is 226.4, and the weight of an atom of hydrogen is 1.64×10^{-24}, and λ_R is 1.2×10^{-11}, we see that if m is the number of grams of radium corresponding to $\overline{n}_R$,

$$4\,\eta = \frac{(77.5 \times 10^7)}{1.64 \times 10^{-24} \times 226.4}\,(4\,\pi\, v_A \times 1.26 \times 10^{-11} m)$$

By plotting the decay curve we find that the initial value of η is 33,400, so that $$mv_A = 404 \times 10^{-18}$$

There is not much certainty with regard to our knowledge of the specific velocities of the active carriers. Laboratory experiments give values ranging all the way between 0.00001 cm/sec to 2.5 cm/sec for a gradient of 1 volt per cm., but the greater number of carriers appear to have specific velocities between 0.5 and 1.8 cm/sec per volt per cm. If we were to take v_A as equal to 1 cm/sec per

volt per cm., i. e., 300 cm /sec per E. S. U. per cm., we should have $m = 1.34 \times 10^{-18}$ grams—i. e., 1.34×10^{-12} curies per cubic meter. On page 29 it was found, making use of the experimental relation of Kurz, that the radioactive content for October 19 was sufficient to account for a production of 0.64 ions per c. c. per second, i. e., to 32×10^{-12} curies per cubic meter, since 10^{-12} curie per cubic meter corresponds to a value $q = 0.020$. This would indicate that the value 1 cm / sec per volt per cm. taken for v_A in the above calculation is far too large. It is probable that the explanation of this is that laboratory experiments have taken too little account of the effect of the slowly moving carriers and that the true average value of v_A is really much smaller than is generally assumed. In view of the great importance of the specific velocity of the carriers in determining the relation between the amount of active material in the air and on the wire, as shown by the foregoing consideration, and of the possible irregularity of this quantity in view of the effects of humidity, etc., upon it, it is to be feared that the Elster and Geitel method can hardly be expected to give results which are even approximately accurate when it is used as a method for determining the actual amount of radium emanation in the air.

Summary and Comparison with Results of Other Observers.

The average values for the whole cruise of the potential-gradient, conductivity $(\lambda_+ + \lambda_-)$, Earth-air current, and activity (expressed in Elster and Geitel units) are, respectively, 93 volts / meter, 2.52×10^{-4} E. S. U., 7.7×10^{-7} E. S. U. per sq. cm., and 23. Practically the only absolute values of the potential-gradient for the Atlantic Ocean are those of Simpson and Wright[21], made in the South Atlantic Ocean in August and September, 1910. According to these observations, the potential-gradient appeared to show a minimum of about 80 volts per meter in the neighborhood of the hours from 9 A. M. to 12 noon, which may be considered to be about the same as the value 93 volts per meter given above, since Simpson and Wright do not claim an accuracy greater than about 25 per cent.

The observations of the present cruise indicate, as far as they go, a general increase of the potential-gradient from summer to winter, which is in agreement with land observations for the daily mean values. The conductivity also shows a general increase from June to September, when a maximum occurs, after which the conductivity

[21] *Proc. Roy. Soc.*, A., v. 85, p. 175, 1911.

falls. This, as already pointed out, is in agreement with Simpson's results in Lapland for the ionic density.

The following table shows the values of the conductivity and radioactive content (A) obtained by other observers in the Atlantic Ocean, the conductivity in all cases corresponding to the hours between 9 A. M. and 12 noon.

Table 9.

Observer	Date	No. of obs'ns	$\lambda_+ + \lambda_-$ (E. S. U. $\times 10^{-4}$)	$\frac{\lambda_+}{\lambda_-}$	A
Burbank (*Dept. Terr. Mag.*),	July, 1905,	31	2.28	....	..
Simpson,	July-Aug., 1910,	..	....	....	6
Kidson (*Carnegie*),	Nov.-Feb., 1909-10,	26	2.44	1.16	12
Kidson (*Carnegie*),	July-March, 1910-11,	46	2.91	1.26	2
Hewlett (*Carnegie*),	Oct.-Dec., 1913,	141	3.49	1.21	12
Johnston (*Carnegie*),	June, 1914,	16	2.09	1.17	15
Johnston (*Carnegie*),	July-Aug., 1914,	14	2.69	1.23	15
Johnston (*Carnegie*),	Sept.-Oct., 1914,	20	2.77	1.20	40

In considering these observations, it must be borne in mind that the time of year has a material effect on the value of the conductivity.

With regard to the radioactive content, the greater number of values for the 1914 cruise range around the value $A = 15$. The average value for the whole cruise is, however, 23, and corresponds to about 12×10^{-12} curies of radium emanation per cubic meter. Even this value is much smaller than would be necessary to account for the conductivity of the air. This conclusion is in agreement with that of most observers, but is contrary to the experience of Eve,[22] who made relative measurements of the activity imparted to a wire on land and on the Atlantic Ocean. Eve found the active content to be about the same in mid-ocean as on land. In this connection, however, it is to be observed that the potential of his charging pile was very small, about 300 volts, and it is just possible that the charge on the wire was mainly controlled by the potential-gradient, as discussed on pages 20-21. During the sea observations, the wire was suspended from the flag halyards, which indicates that it was possibly some distance above the body of the ship. Under these conditions the potential-gradient might induce a charge on

[22] *Terr. Mag.*, v. 14, p. 25, 1909.

it which would cause it to collect many times the amount of activity to be obtained for a charging potential of 300 volts in the absence of the potential-gradient. In fact, for a charging potential as low as 300 volts, it is necessary that very careful account be taken of the effect of the potential-gradient if observations at different places are to be comparable. In connection with this matter, however, it must be observed that Observer H. F. Johnston's mean value for the period from September to October is considerably higher than the general mean value, and is comparable with the amount necessary to account for the smaller values of the conductivity.

None of the atmospheric-electric elements show any marked variations with temperature or relative humidity. Neither are any marked variations with latitude discernible, but there is a suggestion of a maximum for the value of the conductivity in the neighborhood of latitude 50°. The conductivity appears to have an abnormally low value in the immediate vicinity of the American coast, and that this is partly due to a low value of the specific velocities of the ions is borne out by the measurements in Long Island Sound.

In the latter portion of this report an application of the theory of radioactive disintegration is made to the decay curves, and it is shown that, while some of the curves can be accounted for by radium emanation alone, others appear to require the presence of more slowly decaying products than those of radium emanation These latter curves correspond especially to the higher latitudes. In this connection the possibility of the existence of an appreciable amount of thorium *B* is discussed. An attempt to calculate the absolute amount of emanation in the atmosphere directly from the theory of the collection of active deposit, without assuming any empirical relation between the activity and the absolute emanation content, leads to the conclusion that the specific velocity of the carriers, or rather the average specific velocity of the carriers, is much smaller than the values generally assumed from laboratory experiments.

In conclusion, I wish to express my indebtedness to Dr. S. J. Mauchley for verifying the analysis of the activity curves.

Department of Terrestrial Magnetism,
Carnegie Institution of Washington.

Table 10. *New York to Hammerfest.*

Date 1914	Lat. °	Long. °	Wind	Weather	Clouds	Atmos. Press. mm. Hg.	Temp. C. °	Rel. Humid.	λ_+ (E.S.U. $\times 10^{-4}$)	λ_- (E.S.U. $\times 10^{-4}$)	$\frac{\lambda_+}{\lambda_-}$	$\lambda_+ + \lambda_-$ (E.S.U. $\times 10^{-4}$)	Pot.-grad. (volts/m)	Earth-air current (E.S.U. $\times 10^{-7}$)	η
June 11	40.6 N	67.9W	SW 2(a)	bc	3	758	12.6	98	0.17	0.25	0.68	0.42	89	1.2	...
12	40.4 N	64.9W	SWxS 3(a)	bc	2	759	20.8	90	0.24	0.15	1.60	0.39	58	0.8	4600
13	40.0 N	60.0W	SW 3(a)	bc	2	759	19.7	99	0.59	0.45	1.31	1.04	82	2.8	..
16	40.6 N	49.6W	SW 5(a)	....	Ni 4	765	22.6	96	1.46	1.22	1.20	2.68	60	5.4	4500
17	42.7 N	46.9W	SW 4(a)	of	10	766	11.8	100	1.16	0.97	1.20	2.13	112	8.0	
18	45.0 N	43.8W	WxS 4(b)	clear	.....	775	15.8	95	0.56	0.56	1.00	1.12	27	1.0	10200
19	46.1 N	38.7W	W NW 8(b)	....	....	773	13.5	97					14		5800
20	46.4 N	36.0W	S 4(c)	o	S4	773	16.6	84	1.43	0.98	1.16	2.41	84	6.7	3750
21	48.1 N	31.5W	NWxN 5	o	Ni 6	763	16.6	91	2.01	1.78	1.13	3.79	52	6.6	
22	50.5 N	28.6W	W NW 4	obc	Ni 5	.....	15.5	97	1.36	1.13	1.20	2.49	105	8.7	
23	52.7 N	25.3W	NW 4(d)	clear, sunny	.....	764	15.8	87	1.05	0.94	1.12	1.99	86	5.7	22000
24	54.8 N	22.1W	N NW 5	overcast	Ni Cu 4	762	12.8	89	1.90	1.66	1.14	3.56	66	7.8	.
25	57.0 N	18.1W	W SW 4(e)	clear	Ci Cu 3	769	11.6	92	0.85	0.86	0.99	1.71	65	3.7	4500
26	59.6 N	13.4W	S SW 5(f)	hazy	.....	760	12.4	99	0.69	0.77	0.90	1.46	157	7.6	7000
27	62.1 N	8.0W	NW 4(g)	....	Cu 2	755	9.5	92	1.70	1.36	1.25	3.06	89	9.1	10000
28	.....	.....	.....	....	.....	.....	.....		.....	.....		.....	.....	.....	
29	66.8 N	5.1 E	NNW 5	overcast	Ni 6	759	8.4	95	1.46	1.28	1.14	2.74	69	6.3	
30	67.6 N	7.9 E	SE 3	calm	Ni Ci 6	756	8.5	94	1.41	1.07	1.32	2.48	100	8.3	

The following definitions refer only to the column under "Wind." The numbers under that column are on the Beaufort scale.
(a) Wind blowing up from direction of Gulf of Mexico, and having consequently traveled mainly over the sea.
(b) Wind off the American continent. (c) Blowing up the Atlantic from the south. (d) Wind from continent of Greenland.
(e) Blowing up the Atlantic from the Gulf of Mexico. (f) Blowing up the Atlantic. (g) Wind from the continent of Greenland.
The symbols under the columns headed "Weather" and "Clouds" are used in the customary sense.

Table 11. *Hammerfest to Iceland.*

Date 1914	Lat. °	Long. °	Wind	Weather	Clouds	Atmos. Press. mm. Hg.	Temp. C. °	Rel. Humid.	λ_+ (E.S.U. $\times 10^{-4}$)	λ_- (E.S.U. $\times 10^{-4}$)	$\frac{\lambda_+}{\lambda_-}$	$\lambda_+ + \lambda_-$ (E.S.U. $\times 10^{-4}$)	Pot.-grad. (volts/m)	Earth-air current (E.S.U. $\times 10^{-7}$)	η
July 27	73.5 N	16.1 E	NExN 2	o	Ci 6	760	6.1	99	....	....	...	....	121	....	8700
28	73.5 N	16.0 E	calm	o	Ci Cu 5	755	8.4	95	0.96	0.86	1.12	1.82	93	5.6	5500
29	73.9 N	16.0 E	NW 1	o	Ci Cu 3	758	8.3	96	....	....	...	....	115	....	5900
30	74.5 N	16.9 E	SW 1	o	Ci Ci St 3	759	7.2	96	1.18	0.58	2.04	1.76	75	4.4	3100
31	75.2 N	16.2 E	SSW 1	c	Ci St 1	761	7.4	95	....	....	...	....	77	....	4100
Aug. 1	76.5 N	10.0 E	SW 4	o	Ci Cu 6	760	10.4	95	1.42	1.48	0.96	2.87	69	6.6	.....
2	78.3 N	8.8 E	WSW 3	o	Ci Cu 5	762	5.7	97	0.88	0.70	1.26	1.58	45	2.4	7400
8	76.7 N	3.6 E	N 2	o	Ni Cu 5	764	5.7	88	1.74	1.49	1.17	3.23	52	5.6	18400
9	75.0 N	0.5 E	NNE 3	o	Ni Cu 5	763	5.8	99	1.65	1.47	1.12	3.12	63	6.6	20500
11	71.3 N	4.7W	NExE 3	o	Ni Ci 5	753	6.5	90	1.03	1.26	0.82	2.29	81	6.2	6200
12	69.3 N	6.6W	W 3	o	Ni Cu 5	762	8.1	97	1.83	1.78	1.03	3.61	130	15.6	5900
13	67.1 N	6.7W	WSW 5	o	Ni Cu 5	768	7.5	99	1.83	1.65	1.11	3.48	72	8.4	5800
15	65.3 N	4.4W	WxN 4	o	Ni 5	770	8.2	.....	1.32	0.86	1.54	2.18	71	5.2	4400
17	64.7 N	6.2W	NW 2	o	Ni 5	769	9.0	97	1.33	1.69	0.78	3.02	106	10.7	6700
19	64.2 N	8.9W	calm	o	Cu Ni Ci	768	10.5	96	1.65	1.49	1.11	3.14	144	15.1	6900
20	64.0 N	10.5W	SW 2	o	Ni Cu	767	10.5	95	1.60	0.82	1.95	2.42	104	8.4	7500
21	63.4 N	14.3W	SE 3	o	Cu 3	764	11.8	95	1.67	1.40	1.20	3.07	98	10.0	8200

Remarks: Wind velocities generally so small as to render unreliable any conclusions as to the probability of the air having recently passed over land.

TABLE 12. *Iceland to Greenport.*

Date 1914	Lat. °	Long. °	Wind	Weather	Clouds	Atmos. Press. mm. Hg.	Temp. C. °	Rel. Humid.	λ_+ (E.S.U. $\times 10^{-4}$)	λ_- (E.S.U. $\times 10^{-4}$)	$\frac{\lambda_+}{\lambda_-}$	$\lambda_+ + \lambda_-$ (E.S.U. $\times 10^{-4}$)	Pot.-grad. (volts/m)	Earth-air current (E.S.U. $\times 10^{-7}$)	η
Sept. 15	60.6 N	31.0W	NE 4(a)	o	Ci Ni Cu	748	7.6	93	2.20	1.90	1.16	4.10	68	9.3	.....
16	58.5 N	36.2W	NE 5(a)	c	Ni	757	8.0	97	2.17	1.86	1.17	4.03	139	18.7	10300
17	58.2 N	40.2W	NE 3(a)	c	Cu Ni	767	8.3	97	1.64	1.22	1.34	2.86	112	10.7	8500
18	58.1 N	44.0W	E 3	c	Ni	764	7.7	99	1.57	1.34	1.18	2.91	130	12.6	9200
20	58.6 N	53.6W	E 4	fm	Ni	751	5.0	96	1.76	1.69	1.04	3.45	116	13.3	.....
21	56.0 N	53.8W	SWxW 4(b)	om	Ni	751	4.7	89	1.68	1.27	1.32	2.95	118	11.6	32000
22	54.7 N	52.5W	NNW 2(b)	om	Ni	754	5.2	81	1.35	1.26	1.07	2.61	64	5.6	16500
24	52.9 N	50.2W	NW 2(b)	o	Ni Cu Ci	756	7.5	95	1.92	1.67	1.15	3.59	63	7.5	23200
28	48.9 N	47.4W	W 7(b)	c	Ni	760	6.5	93	2.05	1.64	1.25	3.69	117	14.4	.....
29	47.1 N	48.6W	ESE 4	....	....	....	6.5	....	1.48	0.99	....	2.47	....	....	.....
30	47.0 N	50.8W	SW 7(b)	o	Ni	748	10.0	91	1.72	1.48	1.16	3.20	102	10.9	.....
Oct. 1	46.4 N	50.9W	WNW 4(b)	oc	Ni Cu	757	7.5	91	1.90	1.44	1.32	3.34	57	6.3	.....
2	45.2 N	52.4W	NW 7(b)	o	Ni Cu	755	7.5	97	1.79	1.46	1.23	3.25	55	6.0	12600
3	43.9 N	56.7W	N 6(b)	c	Cu	760	9.1	90	1.31	1.64	1.25	2.95	106	10.4	47500
4	43.3 N	58.0W	NW 4(b)	c	Ci	758	14.2	95	0.62	0.51	1.22	1.13	192	7.2	39500
5	42.8 N	60.1W	SE 1(c)	cb	Ci St	764	15.5	91	0.86	0.60	1.43	1.46	131	6.4	30500
6	42.6 N	62.4W	N NE 4(c)	....	....	....	12.2	....	1.88	1.56	....	3.44	....	....	.....
7	41.6 N	66.0W	ExN 3(c)	c	Ni Ci St	766	11.0	85	0.99	1.06	0.93	2.05	141	9.6	23100
8	41.4 N	66.6W	W SW 3(b)	b	....	763	12.5	95	0.55	0.42	1.32	0.97	137	4.4	15100
10	40.8 N	69.4W	S SE 2(c)	b	....	765	15.5	100	0.52	0.33	1.57	0.85	159	4.5	22700

The following definitions refer only to the column under "Wind." The numbers under that column are on the Beaufort scale.

(a) Winds coming from Arctic seas.
(b) Winds coming from American continent.
(c) Winds from Atlantic Ocean.

The symbols under the columns headed "Weather" and "Clouds" are used in the customary sense.

TABLE 13. *Long Island Sound.*

Date 1914	λ_+ (E. S. U. × 10^{-4})	λ_- (E. S. U. × 10^{-4})	$\frac{\lambda_+}{\lambda_-}$	$\lambda_+ + \lambda_-$ (E. S. U. × 10^{-4})	n_+	n_-	$\frac{n_+}{n_-}$	$n_+ + n_-$	v_+	v_-	Potential-gradient (volts meter)	Earth-air current (E. S. U. × 10^{-7})	$\eta \times 10^{-2}$
Oct. 19		0.52				162				0.78			
	0.65				520				0.87				
	0.43				412				0.67				
		0.37				421				0.61			
Mean,	0.51	0.41	1.23	.98	181	442	1.09	923	0.77	0.70	118	3.9	334
Oct. 20		0.57				240				1.65			
		0.54				297				1.26			
		0.26				135				1.34			
	0.53				295				1.25				
Mean,	0.53	0.46	1.15	.99	295	224	1.32	519	1.25	1.42			
Oct. 21		0.09				165				0.38			
	0.10				219				0.32				
	0.11				296				0.26				
		0.09				186				0.34			
Mean,	0.10	0.09	1.11	.19	258	176	1.47	434	0.29	0.36	99	.63	219

SECULAR CHANGE IN THE BRITISH ISLES, 1892-1913.

By C. Chree.

1. The secular change of the magnetic elements in the British Isles has of late years altered so much that a short account of it may be of interest.

Results from a single station for single years are apt to suffer from instrumental errors, but the following 3-year means from Kew Observatory are at least pretty close approximations to the truth.

Table 1. *Secular Change at Kew Observatory (3-year means).*

[The minus sign signifies diminishing westerly declination and northerly inclination.]

Period	Declination (D)	Horizontal Intensity (H)	Inclination (I)
	′	γ	′
1892–1895	—6.6	+25	—2.2
1895–1898	—5.1	+29	—2.6
1898–1901	—4.2	+29	—2.7
1901–1904	—3.7	+18	—1.5
1904–1907	—4.9	+ 4	—1.2
1907–1910	—6.6	— 3	—1.0
1910–1913	—8.7	+ 1	—1.0

In 1901 it almost looked as if the needle were about to retrace its path to the west. As the secular change of D began to accelerate, that of H and I suddenly fell off. Of late years, the change in H has been so small that even its direction is open to doubt. The present position of affairs will be best understood by considering the apparent changes from year to year, given in Table 2, for Greenwich (G), Kew (K), Stonyhurst (S), and Valencia (V). The mean from the four stations is given under M.

Table 2. *Secular Change from 1910 to 1913.*

Year	Declination					Inclination					Hor. Intensity (unit 1γ)				
	G	K	S	V	M	G	K	S	V	M	G	K	S	V	M
	′	′	′	′	′	′	′	′	′	′					
1910–1911	—8.2	—7.9	—6.7	—6.5	—7.3	—0.5	—1.5	—0.8	—0.9	—0.9	— 3	— 1	+ 5	— 3	—1
1911–1912	—8.7	—8.8	—9.8	—8.8	—9.0	—0.3	—0.7	0.0	—1.8	—0.7	— 1	— 4	—14	+10	—2
1912–1913	—9.1	—9.5	—8.1	—9.7	—9.1	—1.3	—0.7	—0.2	—1.1	—0.8	—14	+ 7	—24	— 7	—9
Mean...	—8.7	—8.7	—8.2	—8.3	—8.5	—0.7	—1.0	—0.3	—1.3	—0.8	— 6	+ 1	—11	0	—4

In the case of D, where instrumental changes are least to be feared, the results from the different stations are remarkably similar. In the case of I, the differences are less than would be expected by those familiar with dip circles. In the case of H, the mean results suggest that H is now falling, and at a gradually accelerating rate. This is the conclusion one would naturally draw from what has been observed on the continent of Europe. Until about 1900, H was rising all over the continent. It then passed a maximum, and began to fall in the east of Europe, and the area within which the secular change is a reduction has rapidly extended westwards.

There is, of course, no reason to expect the secular change in any element to be *identical* at stations so far apart as Valencia and Stonyhurst or Greenwich, but the larger irregularities in the H changes shown in Table 2—e. g., the difference between Greenwich and Kew during the year 1912 to 1913—are probably, in part at least, of instrumental origin. The fact is that, to obtain the secular change in H from year to year correct to 1γ, we must take more trouble than we usually do, or else we must devise instruments less liable to alteration than unifilar magnetometers.

If the electrical methods proposed by Professor Schuster and others possess the accuracy anticipated—and their doing so seems likely to be only a question of cost—the near future may see observers at fixed observatories in a superior position; but at present researches requiring an accuracy of 1γ in absolute values must, I think, wait. While higher accuracy in absolute instruments is desirable, it would be a mistake to regard it as of supreme importance at the moment. Increased accuracy in instruments naturally facilitates discoveries of certain kinds. The recognition of small differences, where none are expected, leads, in every branch of science, to discoveries. But a great many investigations still offer themselves which are well within the range of existing instruments.

2. It can hardly be claimed that, up to now, our knowledge of the secular change of the magnetic elements has owed much to theory. That, however, is no reason why any generalizations made by those who have made a special study of the subject should be lightly passed over. Some years ago, Dr. Ernst Leyst[1] supported the view that the secular change of declination is largely dependent on sunspot conditions at the time. He gave figures for Greenwich

[1] *Bull. de la Société Imper. des Naturalistes de Moscou*, 1909, pp. 160-162.

which made the change nearly twice as rapid at sunspot maximum as at sunspot minimum. As the secular change at the same time is widely different in different regions of the globe, any general connection of the kind suggested by Leyst seems to me hardly likely. In a recent work,[2] I showed that Kew data between 1860 and 1902—a longer period than Leyst had considered—gave no support to the theory. In a recent paper,[3] referring to my criticisms, Leyst seems to claim that, whatever may have been the case long ago, secular change in recent years has followed the law he advanced. In support of his contention, he quotes from my book the five earlier of the following data for Kew. I have added the data for 1910 to 1913, and the two final means.

TABLE 3. *Secular Change of Declination at Kew.*

Sunspot maximum years		Sunspot minimum years	
Period	Change	Period	Change
	′		′
1881–1884	—6.13	1887–1890	—5.47
1892–1895	—6.63	1899–1902	—4.10
1905–1908	—5.33	1910–1913	—8.73
Mean......	—6.03		—6.10

Sunspot minimum might have been better represented by 1911 to 1914 than by 1910 to 1913, but final data for 1914 will not be available for some time.

To completely disprove such a theory as Leyst's, it would be necessary to employ a number of sunspot cycles so large that the addition of another would exercise no appreciable influence in the values found for the secular change. During the next sunspot maximum we *may* have a rate of change which will throw even that of recent years into the shade. All we can say with certainty is, that the last sunspot minimum has co-existed with a higher rate of secular change of declination than has existed in England for a large number of years.

[2] CHREE: *Studies in Terrestrial Magnetism*, p. 19.

[3] *Bull. de la Société Imper. des Naturalistes de Moscou*, 1913, pp. 567 and 594.

LETTER TO EDITOR

CORRESPONDENCE CONCERNING THE COMMISSION FOR TERRESTRIAL MAGNETISM OF THE INTERNATIONAL METEOROLOGICAL COMMITTEE.

For the purpose of facilitating correspondence on subjects of a scientific nature during the European war, Prof. Adolf Schmidt, secretary of the Commission for Terrestrial Magnetism, has asked the undersigned to act as intermediary for this correspondence. He accordingly requests that communications or propositions respecting terrestrial magnetism be sent to the undersigned, who will undertake to enter into the necessary correspondence with the Secretary of the Commission or with the members of the Executive Bureau, as the case may be, and communicate the result to the author.

E. van Everdingen,
Institut météorologique royal des Pays-Bas,
De Bilt, Holland.

De Bilt, February 11, 1915.

NOTES.

1. Magnetic work in Egypt. The Physical Service, under the direction of which the magnetic work (observatory and field) is being conducted, according to notice dated Giza (Mudiria) April 24, 1915, has been detached from the Survey Department, and now forms part of the Public Works Ministry. Communications and publications should be addressed: The Director, Physical Service, Dawawyn, Cairo, Egypt.

2. Valencia Meteorological and Magnetic Observatory. Mr. J. E. Cullum has retired from the superintendency of the Observatory and has been succeeded by Mr. L. H. G. Dines.

3. Argentine Meteorological Office. Dr. W. G. Davis, for many years the director of the Oficina Meteorológica Argentina, Buenos Aires, has retired from his duties and is succeeded by Señor Martin Gil. The magnetic survey of Argentina is under the direction of the Meteorological Office; the general survey has been largely completed under Mr. Schultz's charge.

4. Pilar Magnetic Observatory, Argentine. Mr. L. G. Schultz, in charge of the Observatory since its foundation in 1903, has resigned his post and has returned to the United States.

5. Dr. W. Grylls Adams, emeritus professor of natural philosophy in King's College, London, died on April 10, at the age of 79 years.

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME XX — JUNE, 1915 — NUMBER 2

DETERMINATION OF THE HORIZONTAL INTENSITY OF THE EARTH'S MAGNETIC FIELD BY MEANS OF THE DISCHARGE FROM THE WEHNELT CATHODE.

BY C. T. KNIPP AND L. A. WELO.

I. INTRODUCTION.

A common method of determining the ratio of the charge to the mass of an electron is to use a cathode discharge tube and measure the deflection of the beam of particles by a magnetic field; the other necessary relation being obtained, either by observing the fall of potential at the cathode, or the deflection of the rays as they pass between the plates of a condenser.

The fact that the measurement of e/m with a cathode tube involves the deflection produced by a magnetic field, suggests that we have here a method of measuring magnetic fields, provided we assume the ratio e/m. For low velocities of the electron this ratio, 1.765×10^7, is constant and is well determined by measurements on the cathode rays and more especially on the Zeeman phenomenon. This investigation, therefore, concerns itself with the development of such a method for determining the horizontal intensity (H) of the Earth's magnetic field.

Since this field to be measured is always very weak, compared with those employed in the determination of e/m, a form of tube should be chosen which will give a measureable deflection, yet which will not be inconveniently long. Tubes equipped with cold cathodes, such as the Braun tube, impart high velocities of the order 9×10^9cm/sec. to the electrons. The Wehnelt hot-lime cathode, on the other hand, because of the lower potential-differences which can be used, gives velocities of about 1.6×10^9cm/sec., and since the magnetic deflection is inversely proportional to the velocity of the electron, it is obvious that the Wehnelt cathode is advantageous. An additional advantage in using this cathode is

that the active part can be limited to a very small piece of lime placed on the heated platinum strip. With a good charcoal liquid-air vacuum it is possible to get a well defined beam of long range without the use of screens and diaphragms.

II. THE THEORY.

Development of Formula.—Fig. 1 is a sketch of the tube used. The anode is shown at A and the cathode C at a distance l above the screen S. The electrostatic plates of length d and of distance

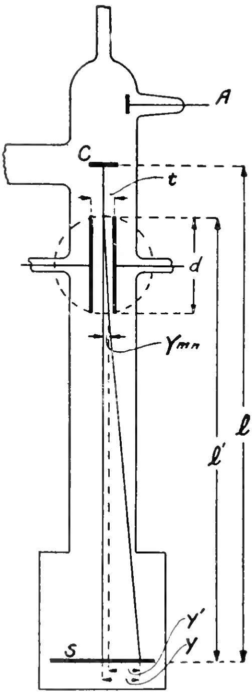


FIG. 1

apart t are shown with their most remote end at a distance l' from the screen. Calling y the total electrostatic deflection, y_{mn} the deflection after the rays have just passed the plates, and y' the additional deflection while on their way to the screen, we have[1] Y being the electric force perpendicular to the plates and v the velocity of the electrons downward:

$$y = y_{mn} + y' = \frac{1}{2}\frac{Ye}{m}\frac{d^2}{v^2} + \frac{Ye}{m}\cdot\frac{d}{v}\cdot\frac{l'-d}{v} = \frac{Ye}{mv^2}d\left(l' - \frac{d}{2}\right)$$

[1] THOMSON, *Conduction of Electricity Through Gases*, 2nd ed., p. 117.

Let $$d\left(l' - \frac{d}{2}\right) = A$$

hence $$y = \frac{AYe}{mv^2} \tag{1}$$

Consider the circle of diameter d, and in position shown, as the boundary of a uniform magnetic field perpendicular to the plane of the paper; writing z, z_{mn} and z' for y, y_{mn} and y' respectively we have for the magnetic deflection:

$$z = z_{mn} + z' = \frac{1}{2}\frac{He}{mv}d^2 + \frac{Hed}{m} \cdot \frac{l' - d}{v}$$

But in this case the Earth's field is effective all the way to the screen, hence the second term is zero since d becomes equal to l', and for this case l' becomes equal to l, and so we have

$$z = \frac{1}{2}\frac{He}{mv}l^2$$

Let $$B = \frac{l^2}{2}$$

hence $$z = B\frac{He}{mv} \tag{2}$$

Now eliminating v between equations (1) and (2) and solving for H^2 we get

$$H^2 = \frac{A}{B^2} \cdot \frac{m}{e} \cdot \frac{Yz^2}{y}$$

But $$Y = \frac{V \cdot 10^8}{t}$$

where V is the electromotive force between the plates measured in volts, and t their distance apart,

hence $$H = \frac{10^4}{B}\sqrt{\frac{Am}{et}}\, z \sqrt{\frac{V}{y}}$$

or, writing $$C = \frac{10^4}{B}\sqrt{\frac{Am}{et}}$$

we have $$H = Cz\sqrt{\frac{V}{y}} \tag{3}$$

Reduction of the Photographs.—It is obvious that the Earth's magnetic field cannot be eliminated for a zero reading of the deflection. To measure this deflection, then, it was found necessary

to place the tube in a frame so that it could be turned about a vertical axis. It is apparent from Fig. 1, since the cathode beam is always deflected in the same direction, that a circle will be described on a photographic plate at S if the plate turns with the tube, the radius of which is the deflection sought. However, the electrostatic field plates turn with the tube, hence the electrostatic deflection changes in direction as the tube is turned. What is gotten, then, when both fields act simultaneously on the beam is not at first thought so apparent; however, the resulting trace on the photographic plate is easily deduced analytically. Let a be the magnetic deflection, and b the electrostatic deflection, and if we first note that the direction of b is fixed relatively to the plate, while a rotates relative to the plate (though it does not rotate relatively to a fixed line) we have, taking rectangular coordinates x and y fixed to the plate, and measured from the center O of the circle described when the magnetic field alone is acting,

$$x = b + a \cos \theta$$

$$y = a \sin \theta$$

where θ is the angle of rotation of the plate. Thus

$$(x - b)^2 + y^2 = a^2$$

which shows that the trace sought is a circle of radius a and center at a distance b from O.

It was found early during the course of the work that there was little hope of securing a permanent electrostatic deflection. As soon as the plates were charged, the beam would jump in a plane perpendicular to the plane of the plates, a distance proportional to the potential-difference applied, but it would not stay there. It would creep back to the zero position, first rapidly and then more slowly. Similar difficulties have been observed in cathode tubes by Thomson[1], Wehnelt,[2] Milham,[3] and others. Thomson traced the effect to the conductivity imparted to the residual gas by the passing cathode rays. He measured the conductivity of the gas and found that it decreased with improved vacuum, so that if a high enough vacuum was reached the beam would stay permanently deflected. The positive and negative ions between the plates diffuse until the positive plate becomes coated with negative ions and the negative with positive ions,

[1] J. J. THOMSON. *Phil. Mag.*, vol. 206, 1897, pp. 293-316.

[2] WEHNELT, *Phys. Zeit.*, 1905, pp. 732-733; *Verh. d. Deutsch. Phys. Gesell.*, 1903, p. 29.

[3] MILHAM, *Phys. Zeit.*, 1901, p. 637.

with the result that the electric intensity gradually vanishes. The Wehnelt cathode ceases to act if the pressure is less than about 0.0008 mm., and no permanent deflection could be obtained within the range of pressures for which this cathode will work. Wehnelt has constructed a Braun tube equipped with this form of cathode and obtained a permanent deflection, but he used a diaphragm which is impracticable here because the particles are deflected magnetically out of the axis of the tube as soon as they leave the cathode.

The work of Milham suggested that use might be made of the jump which he found to be proportional to the change in the potential-difference between the plates. One jump, however, would hardly leave an impression on the photographic plate, so use was made of a commutator. The alternating electromotive force would cause the beam to vibrate across the plate. We should have a straight line traced out on the plate in a plane perpendicular to the plane of the field plates. Referring to Fig. 2, let *A* be

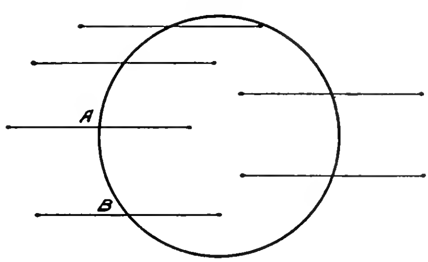


FIG. 2

the first exposure made by applying the alternating electromotive force, the tube being stationary during this exposure. Because of the form of commutator used, the ends of the line are more dense than the line itself. During intervals of zero potential the beam would not have time to creep appreciably from the position of maximum deflection.

Having made an exposure at *A*, the electrostatic circuit is broken and the plates shorted. The tube is now slowly turned and a part of the trace due to the magnetic deflection will be described. At *B* the tube is stopped and an alternating electromotive force again applied. As many exposures as desired may be made for the electrostatic deflection on a given plate. The electrostatic deflection is half the distance between the spots.

III. THE APPARATUS.

Fig. 3 is a sketch of the apparatus used. It consists of an outer wooden frame equipped with leveling screws. The tube is

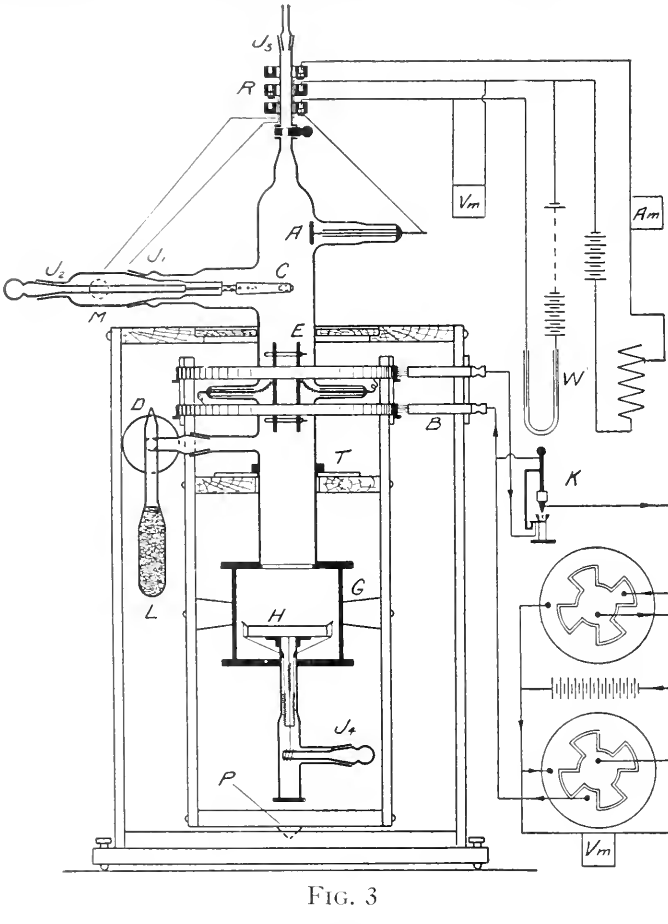


FIG. 3

firmly fastened to the inner frame by clamping with a lining of tape and felt at T and by blocking by means of corks at G placed between the widened part of the tube and the vertical parts of the frame. At P the inner frame rests on a pivot supported at the bottom of the outer frame. The other bearing is the tube itself where it passes through the upper part of the outer frame at E. This opening is felt lined and adjustable. Thus the inner frame and the discharge tube which it supports turns freely about a vertical axis passing through P.

The anode is at A and the cathode is indicated at C. In general the direction that the beam takes is uncertain, hence the cathode must be made adjustable. J_1 is a ground joint, and by turning here the beam can be shifted in a plane perpendicular to the plane of the drawing. It will be seen later that by turning the stem going through the joint J_2 the corresponding adjustment in the plane of the drawing can be made.

The plates which produce the electrostatic deflection are shown below E. They are of aluminum and are rigidly fastened to four hard rubber posts. By placing friction pins in one end of each of the posts these plates are held at any desired position in the discharge tube. Electrical contact is made with the plates by small coiled springs which are fused to the platinum electrodes which lead out through the two side tubes shown. These springs being flexible make good contact and permit of a considerable range up or down for the field plates. The electrodes leading to these field plates are connected, one to each of the amalgamated copper slip rings shown one above and one below the two side tubes, which in turn communicate through the brushes at B and the key K with the commutator circuit.

Near the top of the apparatus at R are three hard rubber rings containing each an annulus of mercury. The upper two are connected to wires which enter the discharge tube through sealed in platinum wires at the dotted circle at M and conduct the heating current to the lime cathode at C. One of these annular contacts (the middle one) serves also as the connection to the negative pole of the high potential battery producing the discharge, the positive pole of this battery connecting through the lower annulus to the anode A.

D is a drying bulb containing P_2O_5 and L is a charcoal bulb. J_3 is a ground glass joint accurately centered to admit the discharge tube being turned freely without binding. Connection beyond J_3 is made to a power-driven Gaede capsule pump.

Referring to the commutator-circuit, the two wheels shown diagrammatically are fastened to the same axle so the reversals are synchronous. When the wheels are in the position shown, relative to the brushes indicated by the spots, the displacement current takes the direction indicated by the arrows provided the plunger of the high insulation key K is down. When the plunger is up, the commutator circuit is broken and the field plates short-circuited.

Reference has been made to the adjustment of the beam in the plane of the paper. In Fig. 4, A is one of the leads leading to the electrode at M, Fig. 3. B is the end of the glass tube going

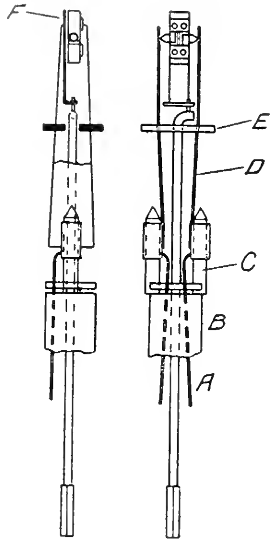


FIG. 4

through the joint J_1. At C are two short solid glass rods fused to the ends of this tube. The two heavy vertical lines are spring brass strips soldered to the two split brass sleeves which fit snugly over the glass rods. E is a thick piece of mica which adds stiffness to the system and serves as a bearing for the central rod, the lower end of which fits into the glass stem going through J_2, Fig. 3. F is a brass strip and at the lower end has a slot cut crosswise, this part being at right angles to the main part of the strip. A pin in the bent part of the long central rod fits into this slot and as the stem through the joint J_2, Fig. 3, is turned, the central rod turns and the cathode proper, mounted on the strip F, is rocked through a considerable angle. The bearings of the cathode are two cone-shaped pins which fit into V-shaped dents in the brass strips. To insure good contact, the strips are adjusted to press against the pins. The platinum strip to be heated and upon which the lime is placed, is mounted on this pivoted cathode in such a manner that the current which enters by one bearing passes through the platinum strip and leaves by the other. A spot of lime 0.2 mm.

in diameter gives a sharp beam, hence the strip need not be over 0.3 mm. wide.

A special plate holder and shutter was devised. This is detailed in Fig. 5, where *A*, a thick glass plate, closes the lower end of the discharge tube. A hole is bored through this plate and a glass tube *B* which supports the shutter is inserted and waxed on with Bank of England wax. This wax was also used in fastening the wide part of the tube to the narrow part, and, it may be remarked, served as a source of lime for the hot cathode. The holder itself is a short brass cylinder closed at one end, about one centimeter deep and nine centimeters in diameter. The shutter was made by cutting a circular sheet of thin aluminum into six segments. Each segment is hinged at its base as shown at 1 in the figure. Since the leaves, to be light-tight, lap over each other, they must come up at different times, and in the figure four of them are shown. Leaf 1 was the first to go up, 2 started next, then 3, and leaf 4, which is seen edgewise, has not yet moved. The leaves are moved by a system of springs and strings and are actuated by turning at the winch *E*, the details of which are given in Fig. 5. The leaves are prevented from opening too far by stops placed as shown and on releasing the springs close of their own weight in the inverse order of opening. The openings shown at the ball and plate at the bottom are convenient when making adjustments.

IV. MANIPULATION.

When making a determination the pump was generally run for over an hour after having closed the bottom of the tube with the plate holder shown in Fig. 5. Half-and-half wax (beeswax and rosin) was used in making this joint air-tight. The charcoal bulb was gently heated during the time of pumping in order to drive off any air absorbed at ordinary temperatures. The shutter of the plate holder was efficient enough to prevent fogging by the light from the flame and the partly darkened room. Having pumped for over an hour, the charcoal bulb was immersed in liquid air for about 15 minutes before making an exposure. A potential-difference of 800 volts from a high-potential battery was then ap-

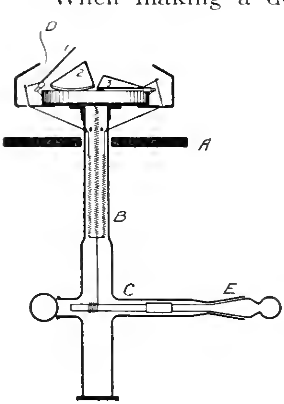


FIG. 5

plied and the resistance in the heating circuit adjusted until the platinum strip glowed a faint red. It was left this way for about 5 minutes. Then the heating current was gently increased until a barely visible beam appeared. The beam increased in intensity, and in a minute or two would give a phosphorescent spot on the leaves of the plate holder which were covered with a thin layer of willemite.

The first adjustment is to shift the cathode so the spot will stay on the plate holder cover during a complete turn of the tube. This is made by turning at the joints J_1 and J_2, Fig. 3. The next adjustment is to produce a well defined spot on the cover, for it is usually a drawn-out band 2 or 3 centimeters in length in a plane perpendicular to the plane of the electrostatic field plates. The beam is not narrow in passing between the plates, but spreads out, and only a bluish glow is visible. Beyond the plates, however, two converging beams are seen, these generally crossing at the lower end of the tube. It was found that the position of crossing depended on the heating current. On varying this it was possible to make the two beams cross right at the screen, or better, a little below, so they would cross at the photographic plate. It is only then that a sharp trace and definite spots are found on the plate. There is more than one value of the heating current or temperature at which this adjustment can be made. It is best to take the lower temperature, for the number of electrons striking the plate is then enormously less and the film will not be in danger of over-exposure while stopping from time to time to apply the potential-difference to the electrostatic plates. Having adjusted the beam to sharpness and having waited long enough so conditions are steady, the tube is turned around again, to make sure that the beam will not go off the plate, before making the exposure. In making the exposure the commutator is first set going and then the key K (Fig. 3) raised to short-circuit the electrostatic plates. Noting the position of the tube, the shutter is opened and the discharge tube turned slowly through a small angle. The key K in the commutator circuit is then lowered and the beam is allowed to oscillate for 8 or 10 seconds. The key is now raised and the tube is again slowly turned through any desired angle, and an exposure due to the electrostatic deflection is again made. This is continued as often as is desired until the tube has been once around, when the shutters are closed immediately. Having admitted air into the discharge tube, the plate holder is removed by gently heating the plate at

the bottom of the tube, since the half-and-half wax is easily melted. In this connection it should be stated that it was found best to renew the lime for each exposure and, since it is practically impossible to get a small new spot over an old one, it is best to renew the platinum strip also.

V. RESULTS.

Measurements were made on 10 photographic plates, numbered 11-20 inclusive. The previous 10 plates were rejected, since they represented the preliminary work, and either lacked the electrostatic deflections because the commutator was not used, or were unreliable because of a faulty voltmeter that was at first used. Reproductions from photographs 13, 15, 17, 18, 19, 20 appear in Plate I, and show improvement in sharpness of trace and definition of spots as experience was gained in adjusting the beam.

To get the magnetic deflection it is best to measure the diameter of the circle in a direction perpendicular to the lines joining pairs of spots, for the circle under certain conditions tends towards an elliptical shape. This is especially true if the discharge voltage is much below 800 volts, giving the electron a low velocity, and hence a large deflection, which may result in the lower ends of the plates interfering with the passage of the beam. There can be no such interference in the plane of the plates.

In measuring the electrostatic deflections it is only necessary to take half of the distance between any pair of spots. It should be remarked that the spots appear much more definite on the negative if it is held against a light, or a white background, than on the prints. Usually 5 measurements were made of the magnetic deflection and 10 of the electrostatic from each plate and mean values used in the calculation of *H*.

TABLE 1.

Photographic Plate	C	V volts	z cms.	y cms.	H cgs.	$H-H_m$
11	0.03504	10.50	2.00	1.75	0.1716	+0.0053
12	0.03378	9.63	2.02	1.73	0.1610	−0.0053
13	0.03504	9.63	1.98	1.78	0.1614	−0.0049
14	0.03504	9.34	1.96	1.59	0.1665	+0.0002
15	0.03504	9.33	2.10	1.77	0.1690	+0.0027
16	0.03504	10.78	2.13	2.18	0.1660	−0.0003
17	0.03504	9.33	2.07	1.66	0.1719	+0.0056

Photographic Plate	C	V volts	z cms.	y cms.	H cgs.	H—Hm
18	0.03504	9.33	2.08	1.82	0.1650	−0.0013
19	0.03504	9.36	2.205	1.941	0.1662	−0.0001
20	0.03504	9.39	2.097	1.881	0.1642	−0.0021
					Mean 0.1663	±0.0008

The data from the ten photographs are collected in Table 1. It is seen that C is the same for all determinations except No. 12, where for one photograph it was changed by lowering the position of the electrostatic-field plates. The lengths of the tube l and l' were measured with a cathetometer, and d and t with a scale, giving l = 46.05 cms., l' = 42.03 cms., d = 10.00 cms., and t = 1.52 cms.

VI. Correction for Irregularities of the Field.

In the development of the formula it was assumed that the field between the electrostatic plates was perfectly uniform and did not extend beyond the limits of the plates. This is not the case, and a correction must be applied.

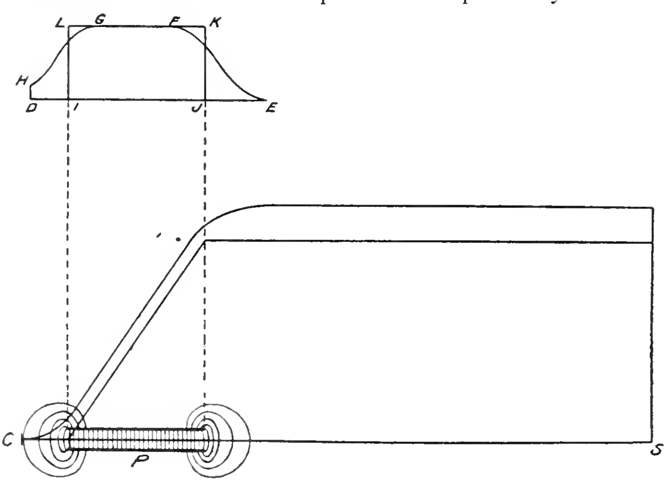


Fig. 6

In making this correction use is made of Pl. XII, Vol. 1, Maxwell's Electricity and Magnetism, where the equi-potential surfaces and lines of force at the edges of a parallel-plate condenser are given. The field at any point in the median plane can be obtained if we assume that the force is proportional to the density of the lines, or inversely proportional to their distances apart. Fig. 6

shows the cathode, electrostatic plates and photographic plate in the positions C, P and S, respectively. The distances between the lines of force along the median plane are accurately measured from Maxwell's figure and their reciprocals plotted as ordinates in the curve $DEFGH$ above so they are proportional to the field at points directly below. The height of the rectangle $IJKL$ gives the field at all points below for the ideal case. The ordinates are of course of the same magnitude for both cases for points far removed from the ends of the plates.

The equation of motion is

$$\frac{d^2y}{dt^2} = \frac{e}{m}\frac{d\phi}{dy}$$

where y is measured in a direction perpendicular to the axis of the tube and ϕ is the potential. A first integral is

$$\frac{dy}{dt} = \frac{e}{mv}\int_0^x \frac{d\phi}{dy}\,dx$$

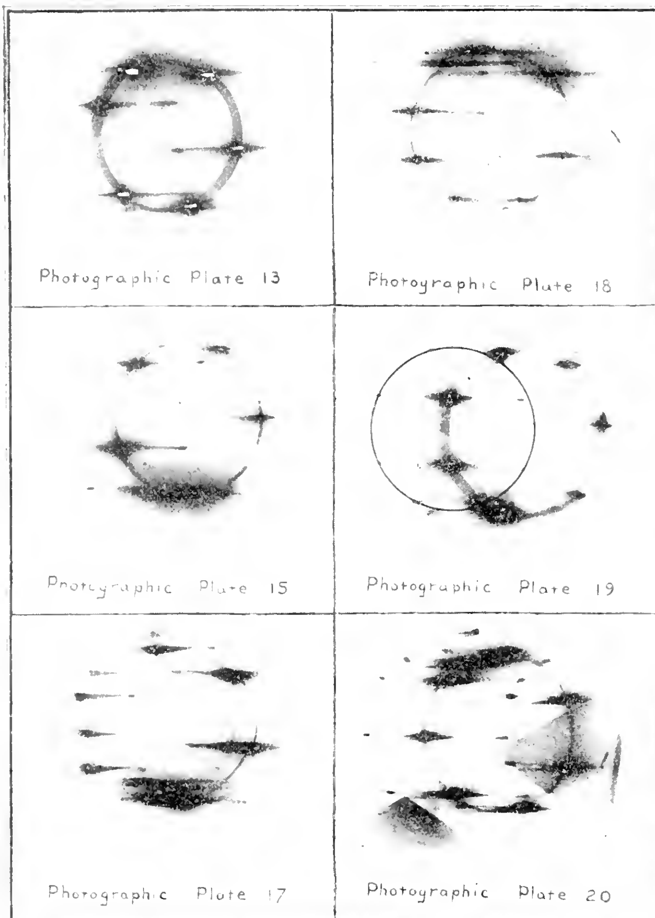
since $vdt = dx$, where x is measured along the axis of the tube.

The integral is

$$y = \frac{e}{mv^2}\int_0^{x_1} dx \int_0^x \frac{d\phi}{dy}\,dx$$

where x_1 is the distance of the photographic plate from the cathode and $\frac{d\phi}{dy}$ is the electric force and is proportional at any point to the ordinates of the curves $DEFGH$ and $IJKL$ so the double integral can be evaluated graphically. To do this DE is divided into centimeters, say, on a drawing of larger scale than here shown and ordinates drawn at each point of division. The areas from the ordinate DH up to each of the ordinates at division points are then measured with a planimeter and plotted as ordinates for the corresponding values of x in the curve below. In this manner the curve with rounded corners was obtained, it being noticed that the curve becomes horizontal after passing the field because there is no increase in area under the curve $DEFGH$. The process was repeated for the rectangle $IJKL$ and the inner curve obtained. The areas under these curves are proportional to the electrostatic deflections and their ratio turns out to be 1.166; so the measured deflection is too large in that ratio. The electrostatic deflection measured on the photographic plate therefore must be divided by 1.166, giving for equation (3)

$$H = Cz\sqrt{\frac{1.166\,V}{y}} = 1.080\,Cz\sqrt{\frac{V}{y}}$$


Photographic Plate 13
Photographic Plate 18
Photographic Plate 15
Photographic Plate 19
Photographic Plate 17
Photographic Plate 20

Applying the correction factor of 1.080 to the mean value of H given in Table 1, we get:

$$H = 1.080 \times 0.1663 = 0.1796$$

The *relative* probable error of this result is $\pm$ 0.0008, or $\frac{1}{224} H$.

In the absence of a corresponding result with a standardized magnetometer, we have no means, at present, of determining the absolute error of our value of H.

VII. DISCUSSION.

The distances l and l', which are large, and d and t are all conveniently measured so the constant C fixed by them can be determined to the degree of accuracy required by the other data. The voltmeter could be read to 1 part in 1000, however, since there were slight fluctuations in the voltage, these readings are probably not correct to more than 0.3 per cent. This is also the accuracy to which the factor correcting for the irregularity of the electrostatic field was determined.

Taking Plate No. 19 as an example, none of the measurements of the diameter of the circle giving magnetic deflection differed from the mean of 5 measurements by more than 1 part in 440. The mean deviation of individual measurements of the electrostatic deflection from the mean of 9 measurements was 2 parts in 388, but this enters to the one-half power, so that both deflections enter the formula to about the same degree of accuracy. The deviations from the mean given in the last column of the table are large, but can be accounted for in part by the presence of electrical circuits in the neighboring rooms of the laboratory. The deviations are consistent with the results always given by Braun tubes, Milham[1] having found that special precautions as to pressure, moisture, and time for settling to a steady state were necessary in order that determinations should agree to 1 per cent. The agreement among the values of H is as good as that among those given for e/m by cathode rays. The best, as far as agreement among the values is concerned, being those by Seitz.[2] In that part of the article devoted to the theory it was shown that the trace obtained with both fields effective should be a circle, but displaced relatively to that obtained with the magnetic field acting alone. Although no permanent deflection was obtained, this deduction is borne out

[1] MILHAM, *Phys. Zeit.*, 1901, p. 637.

[2] SEITZ, *Ann. d. Phys.*, 8, 1902, pp. 235-243.

by passing a curve through the spots due to deflection in one direction, as has been done in Photographic Plate 19. The curve is a circle.

VIII. Summary.

1. A new method of determining H has been developed which depends on the property of the cathode rays of being deflected by a magnetic and an electrostatic field. The well-determined ratio of the charge to the mass of an electron, 1.765×10^7, was assumed.

2. A modified form of Braun tube was used, equipped with the Wehnelt hot-lime cathode adjustable in position, and deflections were recorded on a photographic plate.

3. The difficulty of eliminating the Earth's magnetic field for a zero reading of deflection was avoided by mounting the tube in a frame free to turn about a vertical axis. A second difficulty in connection with the breaking down of the deflecting electrostatic field, owing to ionization of the residual gas, was overcome by the use of an alternating electromotive force.

4. A method of correcting for irregularities at the ends of the electrostatic field plates was devised. Use was made of a diagram giving the lines of force and equi-potential surfaces near the edges of a parallel plate condenser, and the equation of motion was integrated graphically.

5. Ten determinations of H were made and the relative probable error is in the fourth significant place. The agreement among individual determinations is of the same order as that among the best determinations of the ratio e/m, using cathode tubes.

6. The method is another example of the many interesting and useful applications of cathode tubes and is evidence that it is practicable to use the Earth's magnetic field for deflecting purposes when measuring e/m, if that field is known by other means.

The method is due to the senior author who designed and made the tube and took part in the preliminary work. The modification of using an alternating electromotive force to obtain the electrostatic deflection is due to the junior author who made the final observations, the end corrections for the electrostatic field plates, and the necessary reductions and calculations.

Laboratory of Physics,
University of Illinois,
May, 1915.

MAGNETIC DECLINATIONS AND CHART CORRECTIONS OBTAINED BY THE *CARNEGIE* FROM BROOKLYN, NEW YORK, TO COLON, PANAMA, MARCH, 1915, AND FROM BALBOA, CANAL ZONE, TO HONOLULU, HAWAII, MARCH-MAY, 1915.[1]

By J. P. AULT, commanding the *Carnegie*.

(*Observers*: J. P. Ault, H. M. W. Edmonds, I. A. Luke, H. F. Johnston, and H. E. Sawyer. *Minus sign indicates west declination, and plus, east declination.*)

Date	Position		Carnegie	Chart Values				Chart Corrections			
	Latitude	Longitude		Brit.[2]	Ger.[3]	U. S.[4]	C. & G. S.[5]	Brit.	Ger.	U. S.	C. & G. S.
1915	° ′	° ′	°	°	°	°	°	°	°	°	°
Mar. 9	40 23 N	71 48 W	−11.3	−11.6	−11.2	−11.6	.....	+0.3	−0.1	+0.3	.....
10	37 48 N	71 45 W	−9.4	−9.8	−9.2	−9.5	.....	+0.4	−0.2	+0.1	.....
10	36 11 N	71 31 W	−9.3	−8.5	−8.3	−8.6	.....	−0.8	−1.0	−0.7	.....
11	34 17 N	71 27 W	−7.5	−7.2	−7.1	−7.5	.....	−0.3	−0.4	0.0	.....
11	33 05 N	71 35 W	−6.8	−6.3	−6.3	−6.7	.....	−0.5	−0.5	−0.1	.....
12	31 28 N	71 41 W	−5.8	−5.2	−5.3	−5.7	.....	−0.6	−0.5	−0.1	.....
12	30 09 N	71 59 W	−4.8	−4.5	−4.4	−4.7	.....	−0.3	−0.4	−0 1	.....
13	28 26 N	71 33 W	−4.2	−4.0	−4.0	−4.2	.....	−0.2	−0.2	0.0	.....
13	27 23 N	71 00 W	−4.1	−3.9	−3.7	−4.0	.....	−0.2	−0.4	−0.1	.....
15	24 44 N	70 02 W	−3.6	−3.4	−3.1	−3.5	−3.5	−0.2	−0.5	−0.1	−0.1
15	23 29 N	69 17 W	−2.6	−3.2	−3.0	−3.3	−3.3	+0.6	+0.4	+0.7	+0.7
16	23 01 N	69 12 W	−2.6	−3.0	−2.9	−3.1	−3.1	+0.4	+0.3	+0.5	+0.5
16	22 53 N	68 52 W	−3.3	−3.1	−2.9	−3.3	−3.3	−0.2	−0.4	0.0	0.0
17	22 36 N	67 27 W	−4.2	−3.5	−3.4	−3.8	−3.9	−0.7	−0.8	−0.4	−0.3
17	21 50 N	66 37 W	−4.2	−3.6	−3.5	−4.0	−4.0	−0.6	−0.7	−0.2	−0.2
18	20 57 N	66 39 W	−4.0	−3.4	−3.2	−3.6	−3.7	−0.6	−0.8	−0.4	−0.3
19	18 43 N	67 47 W	−3.3	−2.1	−1.8	−2.3	−2.3	−1.2	−1.5	−1.0	−1.0
19	17 46 N	68 53 W	−1.6	−1.5	−0.9	−1.4	−1.4	−0.1	−0.7	−0.2	0.2
20	17 04 N	70 03 W	−0.9	−0.5	0.0	−0.7	−0.7	−0.4	−0.9	−0.2	−0.2
20	16 31 N	70 57 W	−0.2	0.0	+0.5	−0.2	−0.2	−0.2	−0.7	0.0	0.0
21	15 37 N	72 16 W	+0.7	+0.5	+1.2	+0.5	+0.5	+0.2	−0.5	+0.2	+0.2
21	14 52 N	73 23 W	+1.3	+0.9	+1.7	+1.0	+1.2	+0.4	−0.4	+0.3	+0.1
22	13 53 N	74 50 W	+2.0	+1.8	+2.4	+1.7	+1.9	+0.2	−0.4	+0.3	+0.1
23	12 17 N	77 09 W	+3.1	+2.8	+3.4	+3.1	+3.1	+0.3	−0.3	0.0	0.0
23	11 44 N	77 58 W	+3.8	+3.2	+3.8	+3.4	+3.4	+0.6	0.0	+0.4	+0.4
24	10 51 N	79 12 W	+4.2	+3.7	+4.2	+4.0	+3.8	+0.5	0.0	+0.2	+0.4
Apr. 12	8 21 N	79 32 W	+4.7	+4.4	+4.8	+4.5	.....	+0.3	−0.1	+0.2	.....
13	6 16 N	80 12 W	+5.3	+4.9	+5.4	+5.0	.....	+0.4	−0.1	+0.3	.....
14	5 50 N	80 13 W	+5.6	+5.0	+5.5	+5.1	.....	+0.6	+0.1	+0.5	.....
14	5 07 N	80 21 W	+5.4	+5.1	+5.7	+5.4	.....	+0.3	−0.3	0.0	.....
15	4 18 N	80 26 W	+5.7	+5.3	+5.9	+5.7	.....	+0.4	−0.2	0.0	.....
15	3 36 N	80 47 W	+6.0	+5.5	+6.1	+5.9	.....	+0.5	−0.1	+0.1	.....
16	2 52 N	81 28 W	+6.5	+5.7	+6.4	+6.2	.....	+0.8	+0.1	+0.3	.....
16	2 18 N	82 13 W	+6.7	+5.9	+6.6	+6.4	.....	+0.8	+0.1	+0.3	.....
17	2 08 N	83 00 W	+6.8	+6.2	+6.7	+6.5	.....	+0.6	+0.1	+0.3	.....
17	2 10 N	84 25 W	+7.2	+6.4	+6.9	+6.6	.....	+0.8	+0.3	+0.6	.....
18	2 19 N	85 41 W	+7.5	+6.6	+7.0	+6.8	.....	+0.9	+0.5	+0.7	.....
18	2 22 N	86 45 W	+7.6	+6.8	+7.2	+6.9	.....	+0.8	+0.4	+0.7	.....
19	2 11 N	87 40 W	+8.0	+7.0	+7.3	+7.0	.....	+1.0	+0.7	+1.0	.....
19	2 04 N	88 37 W	+7.9	+7.2	+7.4	+7.3	.....	+0.7	+0.5	+0.6	.....
20	2 01 N	89 52 W	+8.5	+7.3	+7.6	+7.5	.....	+1.2	+0.9	+1.0	.....
20	2 20 N	91 01 W	+8.4	+7.4	+7.6	+7.6	.....	+1.0	+0.8	+0.8	.....

[1] For previous tables, see *Terr. Mag.*, v. 15, pp. 57-82, 129-144; v. 16, pp. 133-136; v. 17, pp. 31-32, 97-101, 141-144, 179-180; v. 18, pp. 63-64, 111-112, 161-162; v. 19, pp. 38, 126, 204, 234-235.

[2] From British Admiralty Chart No. 2598 for 1912, referred to 1915.

[3] From Reichs-Amt-Marine chart No. 383, Tit. xiv, No. 1, for 1915, and Tit. xiv No 2 for 1910, referred to 1915.

[4] From lines of equal magnetic declination for 1915 on U. S. Pilot chart No. 1400 of North Atlantic, and on U. S. Pilot Chart No. 3500 of the Central American Waters, and from U. S. Hydrographic Office Chart No. 2406 for 1910, referred to 1915.

[5] From United States Isogonic Chart of the West Indies for 1915.

Date	Position		Carnegie	Chart Values			Chart Corrections		
	Latitude	Longitude		Brit.[2]	Ger.[3]	U. S.[4]	Brit.	Ger.	U. S.
	° ′	° ′	°	°	°	°	°	°	°
1915									
Apr. 21	2 53 N	92 12 W	+ 8.5	+ 7.5	+ 7.6	+ 7.6	+1.0	+0.9	+0.9
21	3 02 N	93 22 W	+ 8.6	+ 7.5	+ 7.6	+ 7.7	+1.1	+1.0	+0.9
22	3 21 N	95 07 W	+ 8.6	+ 7.6	+ 7.6	+ 7.7	+1.0	+1.0	+0.9
22	4 09 N	95 41 W	+ 9.0	+ 7.6	+ 7.6	+ 7.7	+1.4	+1.4	+1.3
23	4 41 N	96 00 W	+ 8.6	+ 7.5	+ 7.5	+ 7.6	+1.1	+1.1	+1.0
23	5 12 N	96 17 W	+ 8.6	+ 7.5	+ 7.5	+ 7.6	+1.1	+1.1	+1.0
24	4 35 N	96 04 W	+ 8.7	+ 7.6	+ 7.6	+ 7.6	+1.1	+1.1	+1.1
24	4 22 N	96 06 W	+ 8.7	+ 7.6	+ 7.6	+ 7.7	+1.1	+1.1	+1.0
25	3 49 N	95 22 W	+ 8.6	+ 7.6	+ 7.6	+ 7.6	+1.0	+1.0	+1.0
25	3 52 N	95 35 W	+ 8.7	+ 7.6	+ 7.6	+ 7.7	+1.1	+1.1	+1.0
26	4 12 N	96 21 W	+ 8.7	+ 7.7	+ 7.6	+ 7.7	+1.0	+1.1	+1.0
26	4 13 N	96 26 W	+ 8.9	+ 7.7	+ 7.6	+ 7.7	+1.2	+1.3	+1.2
27	5 13 N	98 11 W	+ 8.6	+ 7.7	+ 7.6	+ 7.7	+0.9	+1.0	+0.9
28	6 03 N	98 29 W	+ 8.8	+ 7.7	+ 7.5	+ 7.6	+1.1	+1.3	+1.2
29	7 47 N	99 22 W	+ 8.7	+ 7.6	+ 7.4	+ 7.6	+1.1	+1.3	+1.1
29	8 20 N	99 19 W	+ 9.0	+ 7.6	+ 7.3	+ 7.5	+1.4	+1.7	+1.5
30	8 22 N	99 49 W	+ 8.8	+ 7.7	+ 7.3	+ 7.5	+1.1	+1.5	+1.3
30	8 30 N	100 34 W	+ 8.6	+ 7.7	+ 7.4	+ 7.4	+0.9	+1.2	+1.2
May 1	8 29 N	101 34 W	+ 9.1	+ 7.8	+ 7.4	+ 7.5	+1.3	+1.7	+1.6
1	8 51 N	102 42 W	+ 8.8	+ 7.9	+ 7.4	+ 7.6	+0.9	+1.4	+1.2
2	9 37 N	104 02 W	+ 9.1	+ 8.1	+ 7.5	+ 7.7	+1.0	+1.6	+1.4
2	9 55 N	105 05 W	+ 8.9	+ 8.2	+ 7.6	+ 7.8	+0.7	+1.3	+1.1
3	10 12 N	105 58 W	+ 8.9	+ 8.3	+ 7.8	+ 7.9	+0.6	+1.1	+1.0
3	10 17 N	107 07 W	+ 8.9	+ 8.5	+ 7.8	+ 8.0	+0.4	+1.1	+0.9
4	10 14 N	109 06 W	+ 9.3	+ 8.6	+ 7.9	+ 8.1	+0.7	+1.4	+1.2
4	10 39 N	110 29 W	+ 9.0	+ 8.7	+ 8.0	+ 8.2	+0.3	+1.0	+0.8
5	10 58 N	111 49 W	+ 9.1	+ 8.8	+ 8.2	+ 8.3	+0.3	+0.9	+0.8
5	11 18 N	113 04 W	+ 9.2	+ 8.9	+ 8.4	+ 8.4	+0.3	+0.8	+0.8
6	11 46 N	114 48 W	+ 9.1	+ 8.9	+ 8.5	+ 8.5	+0.2	+0.6	+0.6
7	12 35 N	117 31 W	+ 9.3	+ 9.1	+ 8.7	+ 8.6	+0.2	+0.6	+0.7
7	12 56 N	118 43 W	+ 9.4	+ 9.2	+ 8.7	+ 8.7	+0.2	+0.7	+0.7
8	13 29 N	120 18 W	+ 9.5	+ 9.3	+ 8.8	+ 8.7	+0.2	+0.7	+0.8
8	13 47 N	121 26 W	+ 9.8	+ 9.4	+ 8.9	+ 8.7	+0.4	+0.9	+1.1
9	14 20 N	123 14 W	+ 9.8	+ 9.5	+ 8.9	+ 8.8	+0.3	+0.9	+1.0
9	14 57 N	124 49 W	+ 9.8	+ 9.7	+ 9.0	+ 8.8	+0.1	+0.8	+1.0
10	15 37 N	126 50 W	+ 9.9	+ 9.9	+ 9.2	+ 8.9	0.0	+0.7	+1.0
10	16 00 N	127 43 W	+ 9.9	+10.0	+ 9.3	+ 9.0	−0.1	+0.6	+0.9
11	16 40 N	129 33 W	+10.5	+10.2	+ 9.4	+ 9.2	+0.3	+1.1	+1.3
11	17 01 N	130 57 W	+10.1	+10.4	+ 9.5	+ 9.3	−0.3	+0.6	+0.8
12	17 32 N	133 26 W	+10.4	+10.6	+ 9.6	+ 9.5	−0.2	+0.8	+0.9
12	17 34 N	133 42 W	+10.5	+10.6	+ 9.6	+ 9.5	−0.1	+0.9	+1.0
13	18 01 N	135 28 W	+10.6	+10.8	+ 9.7	+ 9.6	−0.2	+0.9	+1.0
13	18 29 N	136 30 W	+10.5	+11.0	+ 9.8	+ 9.7	−0.5	+0.7	+0.8
14	18 51 N	138 07 W	+10.9	+11.1	+ 9.9	+ 9.8	−0.2	+1.0	+1.1
14	19 26 N	139 19 W	+10.9	+11.2	+10.1	+10.1	−0.3	+0.8	+0.8
15	19 39 N	141 14 W	+11.2	+11.3	+10.1	+10.1	−0.1	+1.1	+1.1
15	19 51 N	142 37 W	+10.5	+11.2	+10.1	+10.1	−0.7	+0.4	+0.4
16	19 52 N	143 50 W	+11.0	+11.2	+10.1	+10.1	−0.2	+0.9	+0.9
16	20 01 N	145 12 W	+10.6	+11.1	+10.1	+10.1	−0.5	+0.5	+0.5
17	20 19 N	146 49 W	+10.9	+11.1	+10.1	+10.2	−0.2	+0.8	+0.7
17	20 40 N	148 21 W	+11.1	+11.0	+10.3	+10.3	+0.1	+0.8	+0.8
18	20 49 N	149 58 W	+10.8	+10.9	+10.4	+10.3	−0.1	+0.4	+0.5
18	20 56 N	151 12 W	+10.2	+10.8	+10.4	+10.3	−0.6	−0.2	−0.1
19	21 04 N	153 09 W	+10.7	+10.8	+10.5	+10.3	−0.1	+0.2	+0.4
19	21 11 N	154 09 W	+10.6	+10.8	+10.4	+10.4	−0.2	+0.2	+0.2
20	21 27 N	155 49 W	+10.6	+10.8	+10.5	+10.5	−0.2	+0.1	+0.1
20	21 21 N	157 10 W	+11.0	+10.6	+10.5	+10.4	+0.4	+0.5	+0.6
21	21 14 N	157 40 W	+10.8	+10.6	+10.5	+10.4	+0.2	+0.3	+0.4

MAGNETIC AND ELECTRIC OBSERVATIONS AT KEW OBSERVATORY RELATING TO THE SOLAR ECLIPSE OF AUGUST 21, 1914.

By C. Chree.

The following data (magnetic and electric) relate to the solar eclipse on August 21, 1914, and adjacent days.

In what we did we were partly determined by the circular from Dr. Bauer, and partly by one on behalf of Mr. Carlheim Gyllensköld, who is also interested in the matter. We had only one Ebert apparatus available; our second one was temporarily at Eskdalemuir. It thus appeared best to limit ourselves to collections of positive ions. The Wilson apparatus, which was simultaneously under observation, was used to get a measure of the air-earth current. The potential-gradient data were derived from the water-dropper curves. Normally we observe only at 3 p. m., with the Wilson and Ebert apparatus. But special observations were taken on August 17, 18, 19, 20, 22, and 27, covering the eclipse hours, so as to get comparative data.

The magnetic data are all from curve measurements. We did not take a quick-run trace. The horizontal-intensity data are corrected for temperature, but there was no variation in the temperature correction during the eclipse hours either on the day of the eclipse itself or on the mean of the six days, August 18, 19, 20, 22, 24, and 25, used for comparative purposes. August 23 was omitted, because it was very considerably disturbed. Several of the six days used for comparative purposes were not fairly to be described as quiet days. Individual hours were very sensibly disturbed, e. g., the *D* curve on the 19th had a big depression between the hours 21 and 22 (9 and 10 p. m.), but the values at the actual hours were not very largely affected. Still the mean results from the six days are by no means very smooth.

On the day of the eclipse there was undoubtedly a slight lag in the westerly movement during the time of the eclipse—the kind of phenomenon one would theoretically rather expect to get—but a very similar and slightly larger effect of the same kind occurred at about the same hour on the previous day, so the phenomenon may strike different minds differently. I have thought it well to make a tracing (Fig. 1)—somewhat rough, I am afraid—of the declination traces from about 10:30 a. m., to about 10 p. m.,

on the 20th and 21st, so arranged that corresponding times are at least very approximately on the same ordinate. It will be noticed that there was a very pronounced "bay" on the 20th, centering about 8 p. m., of which there is no visible "repetition" on the 21st. This of course rather acts as an argument against a connection between the much smaller abnormalities visible in the two curves shortly after 12 noon.

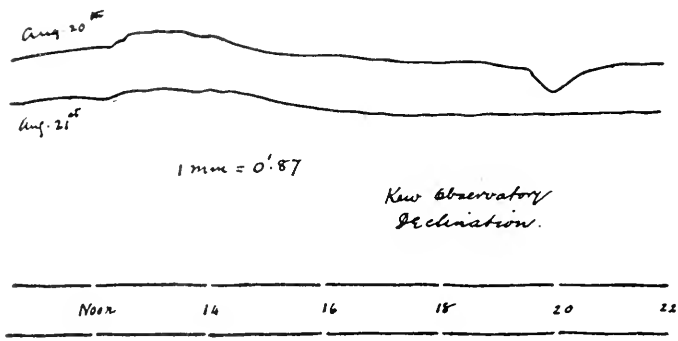


FIG. 1

Owing to electric-traction disturbances, our curves here are not sharp, and are somewhat calculated to mislead those unfamiliar with them.

TABLE 1. *Magnetic Data Observed at Kew Observatory, August,* 1914.

Time (G. M. T.)	*Horizontal Intensity*		*Declination*	
	Day of Eclipse (August 21)	Mean from 6 adjacent days (August 18, 19, 20, 22, 24, 25)	Day of Eclipse (August 21)	Mean from 6 adjacent days (August 18, 19, 20, 22, 24, 25)
h m			° ′	° ′
10 30	.18448	.18454	15 28.6	15 28.2
45	49	54	28.8	28.8
11 00	59	56	29.6	29.5
15	63	60	29.8	30.1
30	68	62	30.4	30.8
45	71	66	30.3	31.4
12 00	71	67	29.9	31.8
15	74	68	30.6	32.3
30	75	74	31.5	33.2
45	74	73	31.7	33.4
13 00	72	72	32.2	33.7
15	74	74	32.2	33.4
30	68	76	31.8	33.6

TABLE 2. *Hourly Magnetic Data Observed at Kew Observatory, August,* 1914.

Hour (G. M. T.)	*Horizontal Intensity*		*Declination*	
	Day of Eclipse (August 21)	Mean for 6 adjacent days (August 18, 19, 20, 22, 24, 25)	Day of Eclipse (August 21)	Mean for 6 adjacent days (August 18, 19, 20, 22, 24, 25)
			° ′	° ′
0 (Mid't)	.18483	.18485	15 27.5	15 25.3
1	79	84	26.2	25.9
2	68	77	26.0	25.6
3	70	72	24.7	24.7
4	69	73	26.2	25.4
5	67	74	26.4	24.5
6	69	72	26.0	23.6
7	63	68	24.9	22.7
8	58	62	23.8	23.1
9	56	55	24.5	24.3
10	51	54	26.7	26.8
11	59	56	29.6	29.5
12 (Noon)	71	67	29.9	31.8
13	72	72	32.2	33.7
14	68	74	32.2	33.0
15	74	80	30.0	31.1
16	85	81	27.6	29.6
17	71	79	26.5	27.7
18	79	84	26.4	26.3
19	82	87	26.2	26.3
20	81	83	26.4	25.2
21	76	84	26.5	25.5
22	76	83	26.5	25.2
23	82	85	26.8	25.0
24 (Mid't)	82	81	26.6	24.5

TABLE 3. *Atmospheric-Electric Observations at Kew Observatory on August* 21, 1914.

Time (G.M.T.)	Potential Gradient	(Air-earth current) × 10^{16} by Wilson apparatus	Time (G.M.T.)	Positive Ions (Charge per c.c) × 10^{20} by Ebert apparatus
h m	volts/metre	amp./cm²	h m	
10 43	145	0.40	10 45	510
49	165	0.85	52	820
55	145	0.95	59	510
11 01	120	0.75	11 06	510
07	125	0.95	13	630
13	110	0.85	20	570
19	110	0.55	26	570
25	125	0.45	33	890
31	165	1.45	40	820
37	110	0.55	47	700
43	110	0.85	54	760
49	105	0.90		
55	80	0.60		
12 01	85	0.75	12 01	510
07	85	1.15	08	630
13	85	0.65	16	890
19	95	1.10	23	570
25	125	1.15	30	570
31	145	1.30	37	700
37	105	0.65	44	700
43	110	0.75	51	700
49	105	0.75	58	700
55	105	0.60		
13 01	95	0.60	13 05	820
07	125	1.05	12	700
13	125	1.20	19	570
19	135	1.35	26	760
25	125	1.20	33	1010
31	125	1.20		
37	135	1.55		

TABLE 4. *Mean Values of Atmospheric-Electric Observations at Kew Observatory, from August* 17, 18, 19, 20, 22, *and* 27, 1914.

Time (G. M. T.)	Potential Gradient	(Air-earth current) × 10^{16} by Wilson apparatus	Positive Ions (Charge per c.c) × 10^{20} by Ebert apparatus
h m	volts/metre	amp./cm²	
10 45	230	1.15	570
11 30	215	1.10	970
12 15	195	1.05	755
13 00	175	0.90	800
13 45	180	0.95	670

LETTERS TO EDITOR

STATUS OF REDUCTION AND PUBLICATION OF THE MAGNETIC OBSERVATIONS MADE ON AMUNDSEN'S NORTHWEST PASSAGE.[1]

You ask to be informed how soon the magnetic observations made by Captain Amundsen on his Northwest Passage will be published. With the aid of two assistants, I am still working out the large mass of material, consisting of the absolute observations of the three magnetic elements and of the magnetograph registrations.

I intend to publish hourly values, local time, for H, D, V, obtained from the magnetograms, and the mean values of the ordinates for every one hour's interval, Greenwich time, 19 months at Gjöahavn, and 6 months at Kings Point. All of the magnetograms, 720 daily plates, will be reproduced in natural size.

Numerous absolute observations were made for determining the constants of the instruments. It has been a troublesome work to find out the most reasonable values by means of observations made so near the magnetic pole. The determinations of the scale values and of the base values for the variometers have been very difficult, especially concerning the vertical intensity, and they are not yet concluded.

The observations occasionally made in the neighborhood of Gjöahavn and towards the magnetic pole will not be reduced until all the constants are settled upon. It is not possible exactly to say how soon the whole work will be published, but I should believe it will take two or three years more until we can begin the publication. The magnetic part of the entire work will probably comprise 2 volumes of text, and 4 volumes of diagrams.

It will not be possible to give a definite position of the north magnetic pole, because the pole, after my opinion, is not a fixed point attached to a certain geographical latitude and longitude, but must be defined as that point on the surface of the Earth where the horizontal intensity at the moment is zero. I expect that the observations from the Gjöa-expedition will show that the point so defined has a mean daily and yearly periodic motion, and besides also more or less irregular displacements. Perhaps it will be possible to find a mean position of the pole, or the form and dimensions of a closed curve within which the pole always is to be found.

AKSEL S. STEEN,
Director of the Norwegian Meteorological Institute.

PROGRESS OF THE MAGNETIC SURVEY OF THE RUSSIAN EMPIRE.[2]

The project[3] of the magnetic survey of the Russian Empire laid before the government by the Academy in 1914, not yet having been approved by it, the activities of the Commission have necessarily been limited to the means appropriated by the Academy and by the provinces.

The survey has been continued during 1914 in two regions; in the

[1] This letter to editor, written (Dec. 30, 1914) shortly before Dr. Steen's lamented death on May 10, 1915, was in response to inquiries received by the Journal at various times regarding the position of the north magnetic pole, as found by Amundsen's expedition.—*Ed.*

[2] Abstract of the Report of the Magnetic Commission of the Imperial Academy of Sciences of Petrograd for the Year 1914; *president,* M. Rykatchew, *vice-president,* E. Stelling; and *secretary,* D. Smirnow.

[3] See *Terr. Mag.* v. 16, pp. 31-32, 1911.

southwest, in Bessarabia, adjacent to the Government of Podolia, the survey of which was completed the preceding year, and in the northeast, in the District of Velsk.

Thanks to the kindness of Count Traily Morkoff, the Commission was able, in the survey of Bessarabia, to make use of the photographic registrations of the magnetic elements at his observatory at Nijni-Oltchadaeff for reducing the observations at the various stations to the middle of the year 1914. The secretary of the Commission installed and adjusted the magnetographs and made the necessary absolute observations, using a Bamberg magnetometer and a Dover dip circle. The work was then continued by Mr. Rosé, physicist of the Observatoire Physique Central Nicolas, and by Mr. Romanovsky, assistant at the Don Polytechnic School, who previously was employed at the Constantin Observatory at Pavlovsk.

The observations at 14 of the stations of the survey were made by Prof. Boulgakoff, of the Petrograd University, and at 55, by Mr. Besikowitch. The work was interrupted because of the war. In the District of Velsk, the work was carried out under the direction of Prof. Leyst, of the Moscow University, who had 4 assistants to help him. Previously the Commission took care to construct a house for a temporary magnetic observatory at Chenkowsk; for this purpose Mr. Oumaroff, employee at the Central Physical Observatory, was sent to superintend the construction of the building. Under the direction of Prof. Leyst, his assistant, Mr. Pricheltroff installed and adjusted the instruments and made during the two months in which the magnetographs were in operation, 10 series of absolute observations to determine the constants of the magnetographs. Mr. Pritcheltroff and the other assistants of Prof. Leyst made observations in the District at 51 points. The floods, the lack of roads and horses, the swarms of gnats, impeded the work and made it hard.

Before and after the field work all the instruments were compared at Pavlovsk with the instruments of the Constantin Observatory.

Besides the surveys mentioned, the Commission, with the support of the Hydrographic Department, organized an expedition for the magnetic survey of the coasts of the Baltic Sea. In this region Prof. Rosenthal, of the Warsaw University, determined the magnetic elements at 15 stations using a Sartorius magnetometer. M. RYKATCHEW.

Petrograd, March 7, 1915.

REDUCTION OF THE MAGNETIC OBSERVATORY WORK OF THE AUSTRALASIAN ANTARCTIC EXPEDITION, 1912-13.

At the request of Sir Douglas Mawson, the undersigned has undertaken the reduction of the magnetograms obtained during the occupation of Adelie Land by the Australasian Antarctic Expedition in 1912-1913. The work is now well in hand at the address below, and it is hoped to have final values tabulated, and most material ready for discussion at the end of the current year.

Various observatories were requested to cooperate with the Expedition in the taking of "quick run" records at prearranged times.[1] In order that the intercomparison of these curves may be as complete as possible, it is desired to collect *copies* of at least the most promising of

[1] *Cf. Terr. Mag.* v. 16, pp. 247-249, 1911.

them, and any details of the others that may be worth consideration. We should therefore be under considerable obligation for the forwarding, at the earliest convenience, of copies of "quick runs" at the following Greenwich mean times, wherever possible giving particulars of base-lines and of scale values:

		G. M. T.			G. M. T.
April	16, 1912	8–10 A. M.	April	18, 1912	5–7 P. M.
May	14, 1912	8–10 A. M.	October	10, 1912	5–7 P. M.
June	11, 1912	8–10 A. M.	January	2, 1913	5–7 P. M.
July	16, 1912	8–10 A. M.			
October	8, 1912	8–10 A. M.			

Also particulars of those at following times are desired:

March	19, 1912	G. M. T. 8–10 A. M.	March	21, 1912	G. M. T. 5–7 P. M.
August	13, 1912		May	16, 1912	
September	10, 1912		June	13, 1912	
November	5, 1912		July	18, 1912	
December	3, 1912		August	15, 1912	
December	31, 1912		September	12, 1912	
January	28, 1813		November	7, 1912	
			December	5, 1912	
			January	30, 1913	

Since the *time* of particular stages of disturbance is *the* item of consideration, it is desirous that special care be taken in the determination of time corrections and in the application of time-marks.

As a still further favor, particulars are requested of curves (preferably copies) for the following *G. M. T's.* The object is a comparison with some Adelie "quick runs" taken simultaneously with extensive auroral displays:

Tuesday, September 9, 1913, 10 A. M.—4 P. M., G. M. T.
Tuesday, September 23, 1913, 10 A. M.—4 P. M., G. M. T.
Wednesday, September 10, 1913, 11 A. M.—3 P. M., G. M. T.

Magnetic Observatory, Christchurch, N. Z., April 10, 1915.

ERIC N. WEBB,
Chief Magnetician, Australasian Antarctic Expedition.

NOTES

6. *Principal Magnetic Storms Recorded at the Cheltenham Magnetic Observatory, Maryland, October 1, 1914 to June 30, 1915.* The following data have been transmitted by the Superintendent of the United States Coast and Geodetic Survey:

Year.	Greenwich Mean Time Beginning. h m	Ending. h	Range D (Declination) ′	H (Hor'l Int.) γ	Z (Vert'l Int.) γ
1914	Oct. 27, 16 14	Oct. 29, 21	26.2	157	104
1915	Mar. 21, 5 50	Mar. 22, 7	31.6	83	65
1915	Apr. 7, 19 41	Apr. 8, 24	17.5	163	59

(*H* characterized by rapid oscillations of about 25γ and with the range occurring abruptly at the beginning.)

1915	June 17, 1 45	June 18, 10	85.8	727	610+

(Vertical-intensity spot of Magnetograph No. 5 passed off the paper at 8^h, June 17, at value 55417γ, and returned on paper at $11^h\ 44^m$; maxi-

4

mum value of Z, 56027γ. Vertical-intensity variometer of Magnetograph No. 1 was upset both by the high Z and the low Z, the magnet having been adjusted by balancing in the meantime.)

7. *Samoa Geophysical Observatory.* According to recent information received regarding this observatory at Apia, the work has not suffered discontinuance because of British occupation of the German possessions in the Samoan Islands. Let us hope that this may be the case generally at observatories situated in the warring countries!

8. *Fourth Cruise of the Carnegie.* The magnetic survey vessel, *Carnegie*, under the command of J. P. Ault, assisted by Dr. H. M. W. Edmonds and by Observers Johnston, Luke and Sawyer, left Brooklyn early last March bound on her fourth cruise. Proceeding to Colon, she passed through the Panama Canal to Balboa, sailing thence to Honolulu, and traversing a region in the Pacific where but few magnetic data had been obtained. She arrived at Honolulu the end of May after a very successful passage. From Honolulu the course will be laid to Dutch Harbor, Alaska, thence to Port Lyttleton, New Zealand. During November 1915 to February 1916, a circumnavigation trip in about latitude 60° South will be attempted.

9. *Personalia.* We regret to be obliged to record the death of *Friedrich Bidlingmaier* at Verdun September 23, 1914; also of *Aksel S. Steen* on May 10, 1915, at the age of 66 years. It is hoped that portraits and biographical sketches of these distinguished and lamented investigators may appear in later issues of the Journal. *Alfred Vialay* was awarded by the Paris Academy of Sciences in 1914 a prize of 500 francs for his contribution to the study of the relations existing between the atmospheric circulation, atmospheric electricity, and terrestrial magnetism. The director, *M. Lecointe*, of the Royal Observatory of Belgium, at Uccles, near Brussels, is at present interned in Holland; he had served in the war as a major of artillery in the Belgian army, and took part in the retreat from Antwerp. The British Association will hold its annual meeting at Manchester September 7-11 next, under the presidency of *Arthur Schuster;* the presiding officer of section *A* (mathematics and physics) will be *Sir F. D. Dyson*. *Wilhelm Trabert* has retired from his posts as professor of physics at the University of Vienna and director of the "Zentralanstalt für Meteorologie und Geodynamik".

ABSTRACTS OF RECENT PAPERS ON ATMOSPHERIC ELECTRICITY

Chree, C.: *Atmospheric Electricity Potential-Gradient at Kew Observatory, 1898 to 1912.*[1]

The paper constitutes a discussion of the results obtained for the potential-gradient measurements made at Kew over a period of fifteen years, from 1898 to 1912. The first portion is devoted to an account of the development of the apparatus employed at Kew and of the means used to reduce the potential-gradient to absolute value. The continuous

[1] Repr. London, *Phil. Trans. R. Soc.*, Ser. A, v. 215, 1915, (133-159).

records are obtained from a Kelvin water-dropper in conjunction with a photographic-recording apparatus. Standardization of the apparatus is obtained by performing simultaneous measurements of the potential-gradient over a plot of level turf. In the present apparatus used for these measurements, an insulated, horizontal bamboo-pole carries a fuse which is connected to an electrometer some distance away. Previous experiments had shown that the length of the bamboo pole was sufficient to insure that the results were not sensibly affected by the support carrying the pole. Measurements of the potential are made by this apparatus at heights of 1 meter and 2 meters above the ground. In this way a measurement of the potential-gradient over the first meter and over the second meter is obtained. A reduction factor r_1 is derived by comparing the first quantity with the simultaneous indication of the water-dropper, and another reduction factor r_2 results from the comparison of the second quantity with the simultaneous indication of the water-dropper. The mean of the two values, r_1 and r_2, is used as the factor for reducing the sets of observations discussed in the paper. The inequality between r_1 and r_2 is partly due to the positive charge in the atmosphere, but measurements of the charge-density with the Ebert ion-counter do not lead to a quantitative explanation of the difference, neither does the variation of $\frac{r_2}{r_1}$ with the season of the year correspond to what might be expected from the measurements of the charge-density. It is concluded that the disagreement is to be explained by the seasonal variations in the shapes of the equipotential surfaces due to the presence of certain vegetation in the vicinity of the apparatus, the foliage being more abundant in summer than in winter.

Prior to 1910, there were several fruit trees near the apparatus used for standardizing the potential-gradient. Certain experiments indicated that the effect of these trees was more important than was at first anticipated, and on cutting them down, just prior to 1910, it was found that the reduction factor was altered in the ratio of unity to 1.91; so that assuming the present factor to be correct, if absolute values of the potential-gradient are required, all values prior to 1910 should be corrected by multiplying by the factor 1.91.

The last two-thirds of the paper are devoted to a discussion of the reduced observations. There are 12 tables of observations and reductions, and several graphs. Table 1 gives the mean monthly values of the potential-gradient from 1898 to 1912, also the yearly means of these quantities. The maximum yearly mean value, (409 volts/meter), occurs in January and December, and the minimum mean value, (207 volts/meter), in June. The results are taken from selected rainless days, free from negative potential, 10 days being usually chosen in each month.

Table 2 gives the monthly mean values of the diurnal inequalities for the whole 15 years, and Table 3 those for the 7 years 1905 to 1912. These tables also contain diurnal inequalities for the whole year and for the three seasons, winter (November to February), equinox (March, April, September and October), and summer (May to August). The data of Tables 2 and 3 are illustrated by graphs. A general inspection of the curves, without a Fourier analysis, leads to the conclusion that

there is no large rapid change in progress in the electrical conditions at Kew, and that the inequalities derived for the 15 years give a close approximation to normal conditions. A Fourier analysis of the curves is made, and the mean monthly and mean seasonal amplitudes and phases of the 24-hour, 12-hour, 8-hour, and 6-hour terms are given for the periods 1898-1912, and 1905-1912. The analysis favors the division of the year into seasons rather than into two periods, summer and winter, for the purposes of exhibiting the characteristic changes in the constants markedly.

For the two epochs studied it appears that there is very little difference between the results for the 12-hour "wave;" there is, however, a marked difference for the 24-hour "wave". The average amplitude is considerably larger in the second period than in the first, though summer shows the opposite phenomenon. In all seasons, the phase angle is decidedly larger in the second period, but the seasonal variation in the phase angle is markedly less in that period. The constants for the 8-hour and 6-hour "waves" are in good agreement for the two periods.

In order to ascertain how the difference between the constants for the 24-hour "wave" comes in, the amplitudes and phases of the 24-hour and 12-hour "waves" were calculated for each individual year from 1898 to 1912. The fluctuation of the 24-hour term is much greater than that of the 12-hour term, and is of such an irregular nature as to render it evident that but little information with regard to the general trend of the 24-hour term could be obtained from one year or two years' data.

In order to obtain an idea as to how the values of the forces responsible for the diurnal changes vary throughout the year, the quantity *A.D.* (signifying average departure from the mean) is plotted. *A.D.* represents the sum of the 24 hourly difference from the means (taken regardless of signs) divided by 24. The range of the diurnal inequalities is also plotted. Both curves show a maximum in February, and a minimum in June, with at least a suggestion of a secondary maximum in Autumn, and a secondary minimum in November. The positions of the principal maximum and of the secondary maximum and minimum, as obtained for the epoch 1905-1912 are different from those for the whole epoch 1898-1912, indicating that the determination of the precise time of occurrence of the maxima and minima would necessitate an analysis extending over a longer period than 15 years.

The annual variation of the potential-gradient is studied by a Fourier analysis of the daily mean values, the diurnal inequality range, the 24-hour amplitude of the diurnal variation and the 12-hour amplitude of the diurnal variation. The Fourier analysis is expressed in terms of an annual and semi-annual "wave". A comparison of the analyses for the 7-year epoch from 1898-1905 with those for the 15-year epoch shows that the results for the daily mean values are in fair accordance for the two epochs, but a comparison of the results for the 7-year and 15-year epochs, in the case of the other quantities analyzed, indicates that even 15 years is too short to give a wholly normal variation in these quantities.

The paper concludes with a comparison of the results at Edinburgh and Kew.

LASSALE, L. J.: *The Diurnal Variation of the Earth's Penetrating Radiation at Manila, Philippine Islands.*[2]

After giving a useful summary of the work of former observers on penetrating radiation, the author describes his experiments on this subject. A diurnal variation was found in the number of ions produced per c.c. per second in a closed vessel, the maximum of 8.96 occurring at 4 P. M. and the minimum of 4.94 at 10 A. M.; the mean value was found to be 7.43.

The author regards it as probable that the main causes of the ionization are the radioactive material in the soil and the radioactive matter in the atmosphere, and hence that the diurnal variation is to be accounted for by variation in the latter, since there is no reason to suppose that the former of these causes might be subject to a diurnal variation.

The air currents at Manila have a diurnal variation, sea breezes blowing at times and land breezes at other times. While the exact nature of the relationship cannot be established from the data available, the author regards it as probable that the minimum effect due to the penetrating radiation must occur at a time when the air over the land is air that has blown from over the sea where it has previously remained long enough to lose a considerable portion of its activity by decay. The maximum which is fairly steady from 3 P. M. to 6 A. M. is then to be considered as due to the air which is over land during this period having previously remained over land for a considerable time.

WRIGHT, J. R., AND SMITH, C. F.: *A Quantitative Determination of the Radium Emanation in the Atmosphere and its Variation with Altitude and Meteorological Conditions.*[3]

The first portion of the paper forms a critical investigation of the charcoal method for estimating the amount of radium emanation in the atmosphere. It will be recalled that in this method, the emanation is absorbed from the air to be tested, by coconut charcoal, from which it is afterwards driven off by heat, and transferred to an ionization chamber, where its effects are recorded in terms of the leak produced in an electroscope. The ionization chamber is afterwards standardized by passing into it a known volume of radium emanation, the latter being obtained by bubbling air through a standard solution of radium bromide. The air is allowed to bubble through the solution for some time before it is used, and it is then usually assumed that the emanation is brought over by the air as fast as it is formed in the standard solution. The authors have carried out experiments which show that this assumption is invalid. They find that the amount of emanation carried over from the solution when the latter is cold, is only about 0.792 of that carried over under the same conditions when it is boiling. They assume that the air carried over from the boiling solution contains the theoretical amount of emanation and use the factor 0.792 as a correction factor for their experiments performed with cold solutions.

[2] *Physic. Rev.*, Lancaster, Pa., Ser. 2, v. 5, No. 2, Feb., 1915 (135-148).

[3] Repr. Manila, *Philippine J. Sci.*, v. 9, No. 1, Sec. A, Feb., 1914 (51-56).

The authors have made experiments to test whether the charcoal showed any signs of becoming saturated by the passage of the emanation. As found by other observers, apparent indications of saturation were obtained in certain cases, but in so far as the amount of emanation which the charcoal absorbed depended not so much upon the amount of the latter as upon its arrangement, it is concluded that the phenomenon was not one of true saturation.

Tests were made to determine whether the charcoal itself contained radium as an impurity, but no evidence of such contamination was found, which is contrary to the experience of Satterly in the case of the charcoal used by him.

The authors have used the charcoal method for determining the radium emanation content at Manila. During a period of 8 months 21 determinations of the amount of radium emanation per cubic meter of air were made, the average value, expressed in its radium equivalent, being 82.5×10^{-12} gram. The radium emanation content is subject to considerable variation, the ratio of the maximum to the minimum being approximately 4 to 1.

In order to determine the variation of the radium emanation content of the atmosphere with altitude, observations by the charcoal absorption method were taken on Mount Pauai, elevation 2,460 meters. The average value obtained for ten observations was 19.1×10^{-12} gram per cubic meter, as compared with 82.5×10^{-12} gram for Manila. The authors regard is as fairly conclusive, therefore, that the amount of radium emanation in the atmosphere decreases with altitude. The range of variation of the emanation content was found to be practically the same for Mount Pauai as that given for Manila.

For both Manila and Mount Pauai the variation of the amount of radium emanation in the atmosphere was found to be fairly closely related to the changes in the weather. Determinations made during fair weather almost invariably gave comparatively high values, while observations taken after or during a period of heavy rains showed a decided decrease.

No definite relation was observed between the variation of the emanation content and a rising or falling barometer. Changes in the humidity, likewise, seemed to have no effect on the radioactivity of the atmosphere. The total wind movement, however, was evidently an important factor in determining the variation.

For Manila a decided variation between day and night exposures was found. The ratio of the average for night exposures to that for day exposures is given as approximately 2 to 1.

W. F. G. SWANN.

KOLHÖRSTER, W.: *Measurement of the Penetrating Radiation for Altitudes up to 9300 Meters.*[1]

[Author's Abstract]

Last summer, on three free balloon ascensions to altitudes of 4100, 4300 and 6300 meters, respectively, I measured the penetrating radiations with a Wulf apparatus of my own construction (No. 1), regarding

[1] Presented before the *Deutsche Physikalische Gesellschaft* at Berlin, July 10, 1914; for fuller publication see *Aerophysikalischer Forschungsfonds Halle, Abhandlung 14.*

which see published reports concerning the same in various places.[2] According to these measurements, the penetrating radiation diminishes with increasing distance above the Earth's surface, up to an elevation of about 700 meters, and after that increases, at first slowly, and then more rapidly, so that at an elevation of about 1600 meters the ionic numbers [intensity of ionization] are again found to be the same as at the Earth's surface. Beyond 4000 meters the increase is considerable so that at still higher elevations a, comparatively, greatly increased intensity of ionization is to be expected, which indeed was found to be the case on the 6300-meter ascent. In contrast with the Wulf instruments used for earlier ascents,[3] especially by Hess,[4] the instrument used for these measurements is especially designed for use in such ascensions. This instrument, for a large range, is almost entirely independent of pressure, thorough tests as to temperature and pressure effects indicating that the results obtained by means of it, may no doubt be considered free from objection in this regard.

In general these results confirmed those of Hess for elevations attained by him (about 5000 meters), and, with an intensity of ionization of 43 ions cm^{-3} sec^{-1} at 6300 meters as against 13.2 ions cm^{-3} sec^{-1} at the Earth's surface, show an increase of a nature not to be ascribed to instrumental defects. In the meantime, upon the basis of experience with Apparatus No. 1, I have had constructed another one (No. III), which I shall describe in detail.

By means of a special arrangement it has been possible to fasten rigidly the fiber mounting of the Wulf electrometer to the reading microscope, so that the bending of the walls due to excess of internal pressure can not effect the suspension of the electrometer. The electrometer system is constructed entirely of nickel-steel and quartz, so as to reduce to a minimum any distortions resulting from differences of temperature between the individual parts. By means of a piece of brass only 15 mm. long, such a compensation is effected that a temperature difference of 1° causes only 3×10^{-8} cm. shortening or lengthening of the system. Other advantages result from a further reduction of 25% in the capacity of the electrometer—it is only 0.99 cm.—from a much improved air-tightness, from smaller external dimensions [of the electrometer], causing a considerable increase in the available volume of air and from the convenient removal of the electrometer in case it is desired to employ other ionization chambers.

On the ascent of June 28, 1914, I made measurements with both instruments. The balloon "Metzeler" (2200 cubic meters) ascended at Bitterfeld, under the guidance of Dr. Everling, and reached an altitude of 9300 meters. I was able to make observations throughout the ascent and especially for an entire hour at elevations from 9100 to 9300 meters. Simultaneous measurements of the intensity of ionization made with

[2] W. Kolhörster, *Phys. Zs.* v. 14, pp. 1066 and 1153, 1913; *Mitt. d. Naturf.-Ges. zu Halle a. S.*, v. 3, No. 5, 1913; *Abhandl. d. Naturf.-Ges. zu Halle a. S.*, New Ser. No. 4, *Halle a. S.* 1914.

[3] Th. Wulf, *Phys. Zs.* v. 10, pp. 152 and 250, 1909.

[4] V. F. Hess, *Phys. Zs.* v. 12, p. 998, 1911; v. 13, p. 1177, 1912; *Wien. Ber.* (2a) v. 121, p. 2001, 1912; v. 122, p. 1481, 1913; *Phys. Zs.* v. 14, p. 610, 1913.

the two instruments agree very well, the differences in any case being not more than 5% of the total intensity of ionization, although the intensity of ionization due to the vessel alone is nearly twice as great for No. I as for No. III. Furthermore, these simultaneous readings fully confirm my previous measurements up to 6300 meters; that is, the values are in agreement with and are an extension of the results previously obtained. In the following short table these results are given together with those previously obtained for comparison.

Altitude above sea level	Differences between ionic numbers at elevation and Earth's surface[1]	
Meters	Values of 1913	Ascent of June 28, 1914
1000	− 1.5	
2000	+ 1.2	
3000	+ 4.0	+ 4.3
4000	+ 8.3	+ 9.3
5000	+16.5	+17.2
6000	+28.7	+28.7
7000		+44.2
8000		+61.3
9000		+80.4

From the good agreement one can scarcely doubt that these values are to be considered as quantitative. The decided regular increase of the radiation is sufficient to exclude all doubt as to the reality of the measurements and therefore as to the increase of the [intensity of] ionization within the enclosing thick-walled zinc vessel. In the absence of any other explanation, one can not refrain from explaining these facts by assuming a radiation of high penetrating power in the upper strata of the atmosphere or in our solar system. It seems impossible that the known radioactive substances of the soil and air are responsible [for this radiation], especially since the preliminary determination of the absorption coefficient according to the well-known law $I = I_0 e^{-\lambda d}$ gives for air at atmospheric pressure the value $\lambda = 1 \times 10^{-5}$ cm^{-1}, whereas for the γ-rays of *RaC*, the value 4.5×10^{-5} cm^{-1} has been determined. The radiation is therefore, as I have previously pointed out, considerably harder [than γ radiations of *RaC*] and is not absorbed to 1% of its value until after passage through 7 km of air at atmospheric pressure.

One may assume that a penetrating radiation of *cosmic origin* exists, which probably, for the most part, comes from the Sun. It is therefore, proposed to test this assumption by means of observations on the Earth's surface under suitable conditions—measurements above and in the water at various times of the day, observations during the solar eclipse of August 21, 1914, in the zone of totality—, and also by means of further balloon ascensions to establish the origin of this radiation.

[1] The author evidently means "difference between intensity of ionization at elevation and at Earth's surface."—*Tr.*

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A. Terrestrial and Cosmical Magnetism

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BAUER, L. A. The Earth's magnetism. The fourth "Halley Lecture" delivered in the schools of the University of Oxford on May 22, 1913. Reprinted, after revision by the author and with added illustrations, from Bedrock, v. 2, No. 3, Oct., 1913, pp. 273-294. Washington, D. C., Smithsonian Inst., Rep. 1913 (195-212 with 9 pls.).

BAUER, L. A. Annual Report of the Director of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, 1914. Repr. Washington, D. C., Carnegie Inst., Year Book No. 13 (298-332 with 3 pls.). 25 cm. [Contains plate showing the magnetic work of the Department of Terrestrial Magnetism, 1905-1914.]

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DOUGLASS, A. E. A photographic periodogram of the sun-spot numbers. Astroph. J., Chicago, Ill., v. 40, No. 3, Nov., 1914 (326-331 with 1 pl.).

DOUGLASS, A. E. An optical periodograph. Astroph. J., Chicago, Ill., v. 41, No. 3, Apr., 1915 (173-186).

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EGYPT, SURVEY DEPARTMENT. Meteorological report for the year 1912. Cairo, Ministry of Finance, Surv. Dept., 1914 (xxii + 237 + xii). 32 cm. [Contains the daily and monthly means of the magnetic elements and the principal magnetic storms as well as observations of atmospheric electricity at Helwan Observatory during 1912.]

FALMOUTH OBSERVATORY. Report of the committee with meteorological tables and tables of sea temperature, for the year 1913, by Wilson Lloyd Fox and Joshua Bath Phillips. Falmouth, J. H. Lake & Co., 1914 (12). 22 cm. [Contains a report of the magnetic work and table of mean annual values of the magnetic declination at the Observatory, Falmouth, for the 25 years, 1888 to 1912, inclusive.]

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Fr. Bidlingmaier

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME XX — SEPTEMBER, 1915 — NUMBER 3

GENERAL RESULTS OF THE MAGNETIC SURVEY OF THE PACIFIC OCEAN.[1]

BY L. A. BAUER AND W. J. PETERS.

A systematic survey of the ocean areas, which include nearly three-fourths of the Earth's surface, was begun at San Francisco just ten years ago. At that time little was known of the magnitude of the errors that were supposed to exist in the magnetic charts covering the high seas; and the Pacific Ocean especially was, with the exception of the voyage of the *Challenger*, nearly a blank as regards magnetic observations. As is well known, the Carnegie Institution of Washington authorized its Department of Terrestrial Magnetism to undertake the magnetic survey of the Pacific Ocean, which has since been extended to include all the oceans.

The first vessel selected for the purpose was the wooden brigantine *Galilee*, which was chartered from Matthew Turner, of San Francisco, in July, 1905. A non-magnetic flying bridge for the installation of the magnetic instruments was built between the fore and main masts. The steel rigging was replaced by hemp, and all iron, as far as was practicable, was removed from the vicinity of the instruments. The deviations were thus reduced to a minimum and, indeed, were smaller than those of any other vessel previously engaged in magnetic observations at sea. But small deviations, though vastly preferable to large ones, since the error in their control is also smaller, require practically the same laborious computations and the same wait for completion of all the swings of a cruise, before final results can be obtained, as are required for large deviations.

On August 5, 1905, the *Galilee* set sail from San Francisco for an experimental voyage to San Diego with the Director of the Department of Terrestrial Magnetism aboard, who planned the arrangement of instruments, inaugurated the methods of observa-

[1] Read at the meeting of the American Association for the Advancement of Science, San Francisco, August 4, 1915.

tions, and trained the observers. Since weather conditions at San Diego are especially favorable for declination-work, this port was finally selected as the chief home port.

Swings of vessel were made for the determination of the ship's deviation-coefficients and constants at the beginning and end of each cruise, and as frequently as was practical at sea and at the various ports of call. These swings were always made, conditions permitting, with both helms on eight points, complete observations, whenever possible, of each magnetic element being secured on each point.

The *Galilee* left San Diego, on her first cruise, under the command of Mr. J. F. Pratt, an experienced officer of the United States Coast and Geodetic Survey, for Honolulu, Fanning Island, the Magnetic Equator, returning to San Diego via Honolulu, at the end of 1905. The two subsequent cruises, 1906-1908, were made under the command of Mr. W. J. Peters. The second cruise included 6 ports of call, and the third 12. The third cruise terminated at San Francisco on May 21, 1908, and after the necessary swings and land observations were made for properly closing the first work, the *Galilee* was returned to her owners on June 5, 1908. Throughout the entire period of the *Galilee* cruises the vessel met with but one accident. She sank in shallow water during a typhoon at Yokohama, in August, 1906, but was raised and repaired ready for sea in ten days.

The experience gained in the *Galilee* work proved conclusively that for the most economical, expeditious, and satisfactory execution of a magnetic survey of the oceans, a *non-magnetic* vessel was necessary. The building of such a vessel, according to the Director's plans, was authorized by the Trustees of the Carnegie Institution of Washington in 1908, and the construction was begun at Brooklyn, in February, 1909, by the Tebo Yacht Basin Company, the architect being H. J. Gielow, of New York. The *Carnegie*, after a short cruise in the North Atlantic in 1909, started from New York, in June, 1910, on a voyage around the world. After cruising in the North and South Atlantic, the *Carnegie*, on January 16, 1912, left the intricate passages of the Eastern Archipelago, to resume the survey of the Pacific Ocean. One year was spent cruising in this ocean, and on January 23, 1913, she rounded Cape Horn homeward bound, and toward the end of the year completed her second cruise.

After another short cruise in the Atlantic in 1914, under the

command of Mr. J. P. Ault, the *Carnegie* is once more (1915), under the same command, in the Pacific Ocean, having entered this time by way of the Panama Canal. She arrived at Honolulu May 21, and at Dutch Harbor, Alaska, on July 20; after the requisite land observations were made, she then proceeded, on August 5, to Port Lyttelton, New Zealand. Thence the *Carnegie* will commence the circumnavigation of the globe in the regions between the parallels of 55° and 60° south latitude. Leaving Port Lyttelton about May 1, 1916, the vessel, on her homeward cruise, will seek to intersect previous tracks of the *Galilee* and the *Carnegie* as often as possible, and cover also such areas where further data are needed. She will close her Pacific Ocean work at Panama about December, 1916.

Thus the first magnetic survey of the Pacific Ocean will be completed by the end of 1916, the accumulated data covering the period 1905-1911. The *Galilee* cruises in the Pacific Ocean, August, 1905, to May, 1908, extended over 61,000 nautical miles, and those of the *Carnegie* will approximate by the end of 1916, 75,000 miles, making a total of about 136,000 nautical miles for the two vessels. During the period August, 1905, to July, 1915, in addition to the observations made in the Atlantic and Indian Oceans, 689 values of the magnetic declination and 578 each of dip and intensity have been observed in the Pacific Ocean aboard the *Galilee* and the *Carnegie*.

Besides the magnetic observations at sea, many others were made on land at each port of call, not only to control the ship's instruments, but also to obtain data for secular change by reoccupying old stations wherever possible, or to establish stations for future use. Valuable instrumental comparisons were made at the magnetic observatories of Sitka, Honolulu, Zikawei, Tokio, Christchurch, and Apia.

Accuracy of the magnetic charts for the Pacific Ocean. The magnitude of the corrections to the world charts of declination and their distribution in the Pacific Ocean is now known. The diagram (Fig. 1) shows the regions of all the largest errors up to June, 1915. In preparing it, the declinations were scaled from charts published in 1898 (United States No. 1700), 1905 (British No. 2598 and German XIV, No. 2), 1912 (British No. 2598), and later editions as they became available during the survey. The corrections are to be added algebraically to the declinations (east declination being considered positive) as scaled from the charts in order to make

them conform to the results of the *Galilee* and *Carnegie* cruises. It is not possible to differentiate between the British, German, and United States charts without adding more figures and thereby losing the salient features of the diagram. Suffice it to say that usually the corrections to the three charts are about of the same order of magnitude and sign with the one exception in the group, just west of the South American coast. In this group the corrections to the British charts were about 1.°3 numerically smaller than those of the German and United States charts, which are the ones shown in this region.

It will be seen that all of the large positive corrections are in an area roughly bounded by the 150th meridian of west longitude, the North American coast and an imaginary line drawn from Panama to a point in latitude 50° south, longitude 150° west. The maximum corrections of over +2° are in the south apex of this triangle. It should, however, be stated that the northern tracks approaching and leaving Sitka are somewhat barren of declination-results owing to the cloudy and foggy conditions that prevail in this region. The largest negative corrections occur in two separate regions. One of these lies between the 150th meridian of west longitude and the Asiatic coast, the other is between the imaginary diagonal from Panama and the South American coast. The maximum negative errors of about 2.°4 are also found in a high latitude.

The many intersections of the tracks of the two vessels afford important information. If the dates of observations made on intersecting passages are widely separated, the results will furnish data for the calculation of the annual variation. If, on the contrary, the elapsed time is sufficiently short, the agreement of the results will be some measure of their accuracy.

Table 1 of *annual changes in magnetic declination for the Pacific Ocean*, determined aboard the *Galilee* and the *Carnegie*, shows the comparison of our values (designated C. I. W.) with those given on the latest British and United States charts; the annual change is not given on the German charts. The annual changes shown in the column headed "C. I. W." are derived from intersections where observations have been repeated after an interval of more than 4.3 years. It will be seen that, with few exceptions, the annual change deduced from the observations of the *Galilee* and the *Carnegie* are numerically larger than those given by the charts. The distribution of algebraic signs agrees in a general way with the signs of the chart corrections shown in Fig. 1. There is, however,

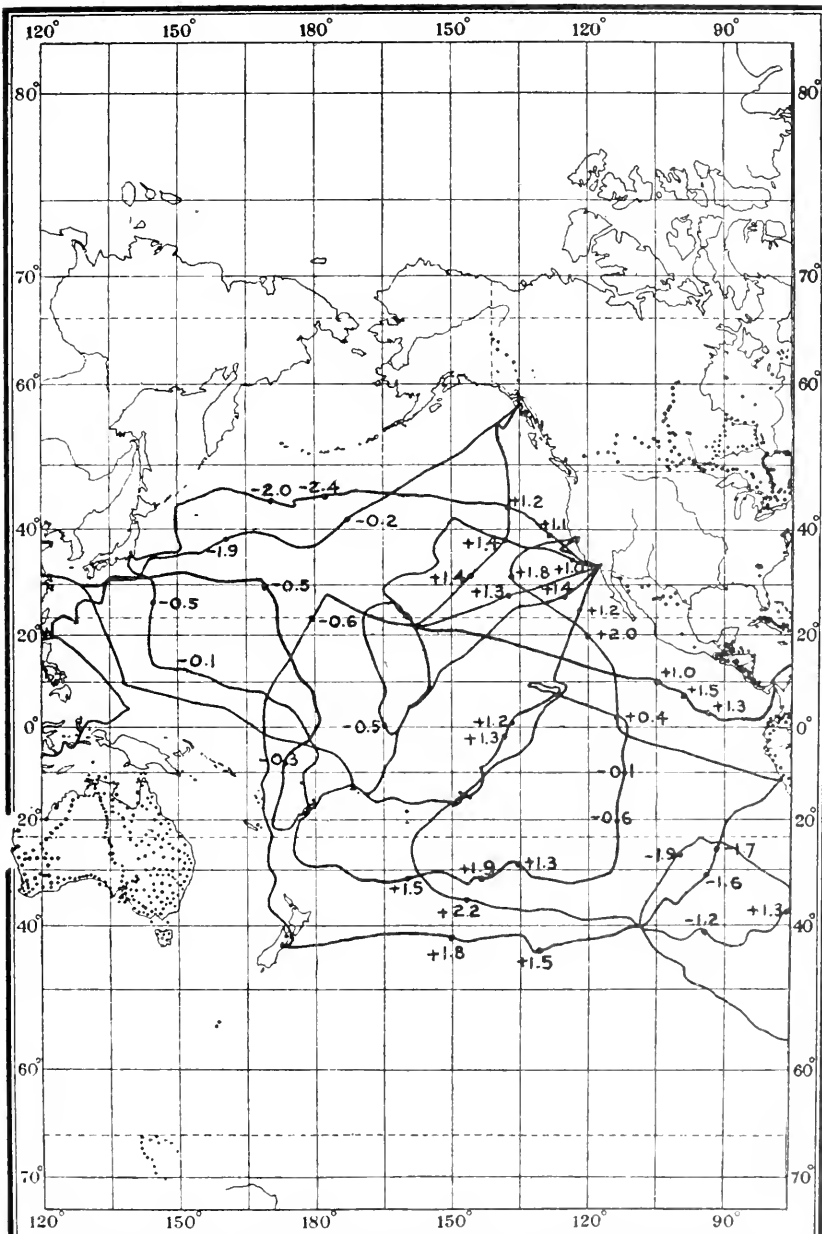

FIG. 1. Showing the general distribution in the Pacific Ocean of the principal chart corrections of the magnetic declination.

one notable exception; the last value of the table is +0.°10, which falls between the larger positive and negative chart-corrections.

Table 1. *Annual Changes in Magnetic Declination for the Pacific Ocean, Determined aboard the* Galilee *and the* Carnegie, *and Compared with Chart Values for the Period* 1906-1913.

[A positive sign indicates a motion of north end of compass needle to east.]

Latitude	Longitude	Approximate Dates	Average Annual Change		
			C. I. W.	British	U. S.
°	°		°	°	°
31 N	217 W	1906.6–1912.3	−0.02	0.00	0.00
26 N	229 W	1907.4–1912.3	−0.01	0.00	0.00
19 N	142 W	1906.2–1915.4	+0.07	+0.05	+0.04
15 N	186 W	1907.8–1912.3	−0.09	+0.02	−0.01
12 N	116 W	1908.3–1915.3	+0.03	+0.06	0.00
6 N	126 W	1907.0–1912.6	+0.10	+0.07	0.00
1 N	113 W	1908.3–1912.6	+0.07	+0.05	0.00
2 S	182 W	1906.4–1912.4	−0.04	+0.02	+0.02
12 S	144 W	1907.1–1912.7	+0.11	+0.07	+0.01
21 S	190 W	1907.9–1912.4	−0.01	+0.03	+0.02
26 S	91 W	1908.2–1913.0	−0.06	−0.02	+0.04
41 S	105 W	1908.1–1913.0	+0.10	......	+0.06
Average change, regardless of sign.........			0.06	0.04	0.02

The annual change on the island of Tahiti, which lies approximately in latitude 17.°5 south and longitude 149.°5 west, as determined by the shore observations of the *Galilee* and the *Carnegie*, is +0.°07. The annual change at Suva, Fiji Islands, approximately in latitude 18° south and longitude 181.°5 west, is −0.°01. The annual change at Honolulu is practically +0.°04. The geographical position is approximately 21° north and 158° west, about midway between the third and fourth values of the table, but somewhat nearer the positive value.

The relative accuracy of the *Galilee-Carnegie* declination results for annual change is different for each determination, since it depends on a different time interval in each case and also upon a greater or less number of stations more or less differently distributed. If we assume the declination-change with locality to be linear between the stations considered, and the probable error of a single station to be ±0°.15, then the probable errors of the tabulated values of the *Galilee-Carnegie* values would be in order from top to bottom, respectively, ±°.02, ±°.02, ±°.01, ±°.02, ±°.01, ±°.02, ±°.03, ±°.01, ±°.02, ±°.03, ±°.02, ±°.02.

Table 2 of *chart corrections for dip and horizontal intensity*, as determined aboard the *Carnegie* in the Pacific Ocean in 1912 and 1915 (to May), shows the corrections that would have to be applied to the values scaled from the only two available charts, the British Admiralty (charts No. 3598 and No. 3603, published in 1906) and the German Admiralty charts (XIV 2a and XIV 2b, published in 1905), to obtain the values given by the *Carnegie*. The dip is considered positive when the north end of the needle is below the horizon; the horizontal intensity is always positive. The *dip corrections* to the British chart are $-5°$ or over in three separate regions, and even reach $-6°.4$. The German chart requires maximum corrections of $+4°.0$ and $+4°.9$, and there are occasional disagreements between the two charts of 7° or more. The *corrections for horizontal intensity* amount to nearly two units in the second decimal place C. G. S. for one chart, and over one unit in the other.

TABLE 2. *Chart Corrections for Dip and Horizontal Intensity as Determined aboard the* Carnegie *in the Pacific Ocean in* 1912 *and* 1915 (*to May*).

Approximate Mean Position		Inclination Correction		Horizontal-Intensity Correction		Approximate Mean Position		Inclination Correction		Horizontal-Intensity Correction	
North Lat.	West Long.	Brit.	Ger.	Brit.	Ger.	South Lat.	West Long.	Brit.	Ger.	Brit.	Ger.
°	°	°	°	cgs	cgs	°	°	°	°	cgs	cgs
29	220	−1.3	+0.8	−.005	−.006	2	236	−1.0	+0.5	−.001	−.002
25	192	−3.1	+1.8	−.011	−.018	11	144	−5.2	+0.4	+.002	+.002
21	237	+0.5	+0.5	−.001	+.002	12	114	−5.8	+1.8	−.002	−.006
18	140	−0.9	−0.2	−.002	−.014	18	187	−1.5	−1.4	−.003	−.002
11	109	−0.5	+2.9	+.006	−.015	28	176	−2.2	−1.8	+.003	−.002
7	227	−0.9	+0.7	−.002	−.005	28	150	−5.0	−0.4	+.004	+.003
5	82	+3.5	+4.0	−.004	−.007	28	127	−6.4	+1.4	+.001	+.010
4	95	+1.0	+4.9	+.006	−.010	29	97	−5.3	+2.0	−.001	+.001
4	128	−1.2	+2.1	+.006	−.010	37	80	−2.0	+1.5	−.002	−.005
2	182	−1.7	+1.4	+.002	−.011	42	104	−5.5	+1.8	−.006	+.008
						54	77	+0.3	+0.9	−.007	−.003

The *accuracy of geographic positions at sea* is dependent on so many factors that it is quite impossible to define it by exact figures based on any one investigation of numerical results. The first consideration would naturally be the magnitude of the probable error of the measured altitudes, and if the observation were a meridianal one this probable error would be the probable error of the resultant latitude at the instant of observation. But as it rarely happens that this instant corresponds to the time of a magnetic observation, the observed latitude must be altered by a quantity which depends upon the run of the ship between observed latitude and the place of the magnetic observations. The error in run may be controlled by astronomic observations preceding and following the magnetic observations, and this procedure is in fact the method employed in the ocean work. But in attempting to assign limits of accuracy we are again confronted with the error in this control which depends upon the stability of the speed and direction of the ocean currents, and the constancy of the leeway and steering. Again, if the observed sun or star be east or west of the meridian, there is an additional uncertainty introduced by the probable error in the chronometer rate. This error, however, need not be considered in the case of the *Galilee* and the *Carnegie*, since it is controlled by time-comparisons at every port available for the purpose, and when appreciable is distributed back over the track covered.

An investigation of some of the three-star determinations of the ship's position made on the *Galilee* indicates that if the sun or star be favorably situated and the weather and sea conditions fair, the average error to be expected in the determination of the geographic position is less than two miles. The error in the control of the ship's run is usually insignificant if the controlling astronomic observations are not more than six hours apart. This is usually the case in the observations of the *Galilee* and the *Carnegie* except in high latitudes where fog and clouds prevail. Of course there are exceptional times when no astronomic observations are possible for several days. The geographic positions for the results of dip and intensity are then more or less uncertain. In the case of declination results, however, no such uncertainty can very well exist, for the sun or star that serves for the declination observations usually permits of at least *fairly* good determinations of position.

Observations for the determination of the *amount of atmospheric refraction* have been made continuously on the *Galilee* and *Carnegie*, beginning with the *Galilee's* third cruise. Two instruments

are now being used on the *Carnegie* in order to vary the conditions. The problem of measuring the atmospheric refraction at sea is a difficult one that has not yet been satisfactorily solved. We can only say at present that the *Galilee* and *Carnegie* results in this work do not indicate presence of any serious error in the ordinary nautical tables.

Probably the most important of recent contributions to observational data in *atmospheric electricity* is the series of observations obtained on the cruises of the *Galilee* and *Carnegie*. The observations consisted in the measurements of potential-gradient, the conductivity, and the radioactive content of the atmosphere, besides the usual meteorological observations. Perhaps the most important result was a confirmation of the somewhat remarkable phenomenon that, while the conductivity over the ocean is as large or larger than over land, the radioactive content is much smaller. The values of the potential-gradient at sea were of the same order of magnitude as those on land.

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MAGNETIC DECLINATIONS AND CHART CORRECTIONS OBTAINED BY THE *CARNEGIE* FROM HONOLULU, HAWAII, TO DUTCH HARBOR, ALASKA, JUNE-JULY, 1915.[1]

By J. P. Ault, Commanding the *Carnegie*.

(*Observers:* J. P. Ault, H. M. W. Edmonds, I. A. Luke, H. F. Johnston, and H. E. Sawyer. *Minus sign indicates west declination, and plus, east declination.*)

Date	Position		Carnegie	Chart Values			Chart Corrections		
	Latitude	Longitude		Brit.[2]	Ger.[3]	U. S.[4]	Brit.	Ger.	U. S.
1915	° ′	° ′	°	°	°	°	°	°	°
June 29, July 3	21 15N	157 58W	+10.7	+10.5	+10.3	+10.4	+0.2	+0.4	+0.3
July 4	22 10N	158 38W	+10.6	+10.7	+10.6	+10.6	−0.1	0.0	0.0
4	23 27N	159 00W	+11.0	+10.9	+10.9	+11.0	+0.1	+0.1	0.0
5	25 01N	159 46W	+11.5	+11.1	+11.2	+11.4	+0.4	+0.3	+0.1
5	26 22N	160 34W	+11.6	+11.3	+11.5	+11.8	+0.3	+0.1	−0.2
6	27 32N	161 02W	+12.0	+11.5	+11.8	+12.0	+0.5	+0.2	0.0
6	28 30N	161 08W	+12.2	+11.6	+12.0	+12.3	+0.6	+0.2	−0.1
7	29 22N	161 14W	+12.7	+11.8	+12.2	+12.4	+0.9	+0.5	+0.3
7	30 14N	161 19W	+12.8	+11.9	+12.5	+12.5	+0.9	+0.3	+0.3
8	30 52N	161 21W	+12.8	+12.0	+12.7	+12.6	+0.8	+0.1	+0.2
8	31 50N	161 27W	+12.9	+12.2	+12.9	+12.7	+0.7	0.0	+0.2
9	32 51N	161 26W	+13.3	+12.5	+13.2	+12.9	+0.8	+0.1	+0.4
10	36 26N	161 13W	+14.5	+13.4	+14.0	+13.6	+1.1	+0.5	+0.9
11	37 17N	163 10W	+14.1	+13.2	+13.8	+13.7	+0.9	+0.3	+0.4
11	37 50N	164 33W	+13.8	+13.1	+13.7	+13.5	+0.7	+0.1	+0.3
12	38 40N	166 05W	+14.2	+13.0	+13.5	+13.2	+1.2	+0.7	+1.0
12	39 30N	167 28W	+13.5	+12.9	+13.3	+12.9	+0.6	+0.2	+0.6
13	40 12N	168 58W	+12.9	+12.6	+13.0	+12.6	+0.3	−0.1	+0.3
14	41 03N	170 31W	+12.4	+12.3	+12.7	+12.2	+0.1	−0.3	+0.2
14	41 18N	170 28W	+12.7	+12.4	+12.7	+12.3	+0.3	0.0	+0.4
15	42 12N	170 20W	+12.6	+12.5	+12.9	+12.4	+0.1	−0.3	+0.2
15	42 33N	170 20W	+12.9	+12.6	+12.9	+12.4	+0.3	0.0	+0.5
16	43 52N	170 14W	+12.8	+12.9	+13.1	+12.5	−0.1	−0.3	+0.3
16	44 00N	170 12W	+12.8	+13.0	+13.1	+12.6	−0.2	−0.3	+0.2
17	45 06N	169 59W	+13.2	+13.2	+13.2	+12.9	0.0	0.0	+0.3
18	49 03N	169 30W	+13.8	+13.9	+14.0	+13.8	−0.1	−0.2	0.0
18	50 00N	169 36W	+14.0	+14.0	+14.0	+13.9	0.0	0.0	+0.1
18	50 10N	169 36W	+14.0	+14.1	+14.1	+14.0	−0.1	−0.1	0.0
19	52 21N	170 06W	+14.1	+14.2	+14.1	+14.2	−0.1	0.0	−0.1
19	53 00N	169 11W	+14.4	+14.8	+14.8	+14.7	−0.4	−0.4	−0.3
23	53 54N	166 32W	+16.5	+16.3	+16.1	+16.5	+0.2	+0.4	0.0

[1] For previous tables, see *Terr. Mag.*, v. 15, pp. 57-82, 129-144; v. 16, pp. 133-136; v. 17, pp. 31-32, 97-101, 141-144, 179-180; v. 18, pp. 63-64, 111-112, 161-162; v. 19, pp. 38, 126, 204, 234-235; v. 20, pp. 69-70.

[2] From British Admiralty Chart No. 2598 for 1912, referred to 1915.

[3] From Reichs-Marine-Amt Chart Tit. XIV, No. 2 for 1910, referred to 1915.

[4] From U. S. Hydrographic Office Chart No. 2406 for 1910, referred to 1915.

ON THE ORIGIN AND MAINTENANCE OF THE EARTH'S CHARGE.[1] PART I.

By W. F. G. Swann.

Introduction. The above subject will be discussed in two parts. Part I, which comprises the present communication, is devoted to a discussion of certain matters of a general nature which must be considered in connection with the formulation of any theory of the cause and maintenance of atmospheric-electric phenomena. A consideration of the various possible types of hypotheses is made, and a short discussion of former theories is given, more particularly in the light of the above considerations. In Part II, which will appear in a future number, it is proposed to consider in greater detail a particular class of hypotheses, provisionally formulated, for the coordination of the main phenomena of atmospheric electricity.

Part I. Discussion of General Phenomena.

It is an established fact that at practically all times and in all places the atmospheric potential-gradient is of such a sign that the potential increases with the altitude. It consequently results that there is a negative charge distributed over the surface of the Earth, the surface density σ of the charge being given by the relation $4\pi\sigma = X$, where X is the potential-gradient.

In view of the fact that the atmosphere is a conductor of electricity, the negative charge is continually being dissipated, and the problem of how it is renewed has for long been one of the most puzzling in atmospheric electricity. No escape from the difficulty is possible on the grounds that the loss per second is very small compared with the amount present, for if λ is the conductivity of the air, measured in the vicinity of the ground, and X is the potential-gradient at the same place,

$$\frac{-d\sigma}{dt} = X\lambda$$

where σ, the surface density, is given by $\dfrac{X}{4\pi}$.

Thus, $\dfrac{-dX}{dt} = 4\pi\lambda X$, and $X = X_0 e^{-4\pi\lambda t}$

[1] Basis of a paper presented for the author by Dr. L. A. Bauer at the special meeting on Atmospheric Physics of section B of the American Association for the Advancement of Science, San Francisco, August 5, 1915.

X_0 being the value of X at the time $t = 0$. Since λ = about 3×10^{-4} E. S. U., X would thus fall to one-tenth of its initial value in ten minutes, if the supply of charge to the Earth were not renewed continually.

In addition to the Earth being negatively charged, the atmosphere is positively charged. Thus the potential-gradient decreases with the altitude, its value being, in fact, given at any altitude by the relation $X = 4\pi(\sigma - \sigma_1)$, where σ is the surface density of negative electricity on the Earth, and σ_1 is the quantity of positive electricity contained in a column of air reaching from the Earth to the altitude in question, and with a base 1 sq. cm. in area. The fact that the potential-gradient diminishes to practically a zero value at high altitudes thus drives us to the conclusion that the positive charge in the atmosphere must be about equal to the negative charge on the Earth. Any theory which is to be in line with the facts must consequently account for the existence of this positive charge in the atmosphere, and for its maintenance, as well as for the existence of the negative charge on the surface of the Earth.

Effect of increase of conductivity with altitude. If, neglecting for the moment the effects of electric convection-currents, we are prepared to admit that the vertical conduction-current is constant with the altitude, the known fact of the increase of atmospheric conductivity to a high value at great altitudes would of itself contain the explanation of the positive charge in the atmosphere, for if there were no positive charge, the potential-gradient would be constant at all altitudes, and considering any layer enclosed between two horizontal planes, we see that the current (measured downwards) flowing into the layer through the upper plane would be greater than the current flowing out of the layer through the lower plane, so that there would be an accumulation of positive electricity in the layer. The same argument applies to each of the layers, and so the accumulation of positive electricity would go on until the diminution of potential-gradient with altitude, resulting from this phenomenon, just sufficed to provide for the constancy of the conduction current in spite of the increase of conductivity with altitude. Obviously, if the conductivity at great altitudes is very large, the potential-gradient will have to be correspondingly small; in this case the positive charge in the atmosphere will balance, and will be equal to the negative charge on the Earth.

In the above remarks, in order to render the mechanism of the phenomenon clearer, we have based our argument on the con-

stancy of the Earth-air current with altitude. The argument does not involve absolute constancy of this element, however. Provided that the ratio of the current density to the conductivity diminishes with altitude until at high altitudes it attains a value relatively small compared with its value at the Earth's surface, the potential-gradient, which is equal to this ratio, will diminish likewise. The conclusion then is necessitated that the positive charge in the atmosphere is equal to the negative charge on the Earth. A condition of affairs in which the vertical conduction current is constant of course involves a continual conduction of negative electricity outwards from the atmosphere.

Possibility of a general electrical circulation in the atmosphere. At first sight it might seem that constancy of the vertical conduction current-density is a primary necessity, since absence of this condition would apparently lead to a *continual* increase of electricity in any layer bounded by horizontal planes through which the conduction current-density was not the same. We shall deal with this matter more fully later, but in the meantime it is to be observed that if the vertical conduction current-density is constant, we have to explain what becomes of it when it reaches the outer limits of the atmosphere. We are confronted with two alternatives. Either the current must be dissipated into space or it must turn so as to flow in a horizontal direction. In the latter case it will be necessary for it to find some downward path where it can return to the Earth again, as otherwise there will be a perpetual accumulation of electricity in the upper atmosphere. Quite apart from the fact that no place has been found where the vertical negative current is always downward, however, the assumption of a circulation of the kind in question would immediately involve us in a serious difficulty. For suppose that the circle, Fig. 1, represents the Earth, so that AB represents the direction in which positive electricity would move under normal conditions. Let us suppose that there is some point C where the positive current flows away from the Earth. Then of course we shall have to establish a circulation so that the current will flow through the Earth along BC, and then back to A along DA. Now suppose we call the potential of B zero, so that the potential of A is perhaps 100,000 volts. The Earth is practically a perfect conductor of electricity, as compared with the atmosphere, so that the potential of C will be practically zero. The potential of D will have to be about $-100,000$ volts, however, and, while the conditions are such that the electricity can flow along the path

$ABCD$, we are confronted with the difficulty of explaining how it can flow up hill from D to A. There are only two possible ways of making a current flow in a closed circuit: we must have a battery or its equivalent in the circuit, or there must be an electromotive

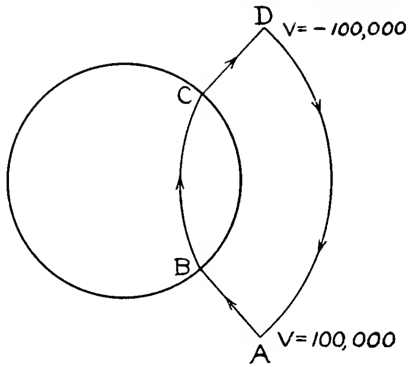

FIG. 1

force arising from electro-dynamical causes, such, for example, as a continual change of magnetic flux through the circuit.

Any attempt to obtain electromotive forces of the necessary order of magnitude by a consideration of changes of flux through circuits arising from the diurnal variations of the Earth's magnetic elements results in values for the electromotive force enormously smaller than would be necessary to account for a circulation of the above kind. In order to account for the diurnal variation of the Earth's magnetic elements, Schuster[2] has considered the electromotive forces arising from the horizontal motion of the air of the upper atmosphere across the Earth's magnetic lines of force. Quite apart from the fact that the nature and distribution of the electrostatic field accompanying this phenomenon would not be such as to qualitatively correspond to the facts of atmospheric electricity, it is easy, by considering special examples, to see that the order of magnitude of the electrostatic fields arising as the result of air motion of reasonable velocity is far too small to have any bearing of importance on the problems of atmospheric electricity. We must thus forego any attempt to include atmospheric-electric phenomena under the scheme which Schuster has found fruitful in its applications to certain problems of terrestrial magnetism.

[2] The Diurnal Variation of Terrestrial Magnetism. *Phil. Trans.*, S. A., vol. 208, pp. 163-204, 1908.

Hertz[3] has considered the effects arising from the rotation of the Earth in its own magnetic field, but here again it is possible to show that the resulting phenomena are too small and are of the wrong type to be of importance in the problems of atmospheric electricity.

Thus the only phenomena which are obviously available for the possible explanation of a circulation of the kind referred to above are unsuitable.

Possible types of hypothesis. Let us now consider in a general way the various types of hypothesis which it would be possible to make to account for the general nature of the phenomena to be explained.

(1). We may imagine that negative electricity is fed into the Earth from the outside in some unspecified manner. In this case it will be necessary to assume that the vertical conduction-current is dissipated again into space.

(2). We imagine that, as the result of some unspecified agency, other than conduction, there is a deposition, or the equivalent of a deposition, of electricity in the atmosphere and Earth, the net amounts for the atmosphere and Earth being equal but opposite in sign, positive for the former and negative for the latter. We may then suppose that, in opposition to this influence, the vertical conduction current is continually endeavoring to bring about a union or reunion of the two kinds of electricity. We may further postulate that the supply is taking place uniformly all over the globe.

(3). We may formulate an hypothesis similar to (2), except that the supply is supposed to take place over only a limited region at any one time.

Hypotheses of the first type. Considering now hypotheses of the first type, we see that, in view of the fact that the Earth is a good conductor of electricity, if the atmosphere were uniform in its electrical properties (dielectric constant, etc.) at points of the same altitude, the negative charge would distribute itself uniformly, quite independently of any considerations as to whether it was supplied uniformly at all places, and there would result a potential-gradient and a vertical conduction current in the atmosphere. As shown on pp. 106-107, the known fact of the increase of conductivity with altitude to a high value at altitudes of ten kilometers or so would be sufficient to account for the fact of the positive charge in the atmosphere below that level being sensibly equal to the negative charge on the Earth. It is desirable, however, for us to follow the

[3] Hertz, *Miscellaneous Papers*, p. 107.

negative current up into the higher regions of the atmosphere in order to ascertain whether it would be likely to encounter any difficulty in getting away. As we ascend to very great altitudes the ordinary theory of conduction must be modified, for the gas becomes very attenuated. The negative ions themselves would, according to modern notions, revert in greater and greater proportion to the form of pure electrons. In the outermost regions the free paths of these electrons become longer and longer as the gas becomes more and more attenuated, and it is obvious that eventually conditions must so arrange themselves that the whole current is carried by these negative electrons instead of, as in the lower atmosphere, part being carried by negative ions and part by positive. If the electrons are to be able to get away into space, it is necessary that in these extreme outermost regions of the atmosphere, where the mean free paths of the electrons are infinitely long, there shall be an electric field whose influence on the electrons shall be just greater than the gravitational attraction; i. e., the net total negative charge on the Earth and atmosphere must be slightly greater than the net total positive charge. It is easily seen that the necessary excess of the negative over the positive charge is very small.[4] When we consider the effect of the motion of the electrons in the Earth's magnetic field, the argument assumes a somewhat more complex nature, though the general features are not altered. On such a theory as the above, the chief seat of the explanation of the diurnal and annual variations of the potential-gradient and Earth-air current-density would have to be found in the diurnal and annual variations of the electrical properties (conductivity, etc.) of the air, since it would be unreasonable to postulate any annual or diurnal variation in the supply of electricity to the Earth as a whole.

While it has appeared of interest to trace out the broader conse-

[4] If Q is the excess negative charge necessary to balance gravitation and m is the mass of the electron, and if the ratio of mass to weight is the same for an electron as for ordinary matter,

$$\frac{Qe}{r^2} = \frac{mg_0\, r_0^2}{r^2}$$

where r_0 is the radius of the Earth, r the length of the radius vector to the point at which the effects are being compared and g_0 is the acceleration due to gravity at the Earth's surface.

$$\text{Hence} \quad \frac{Q}{r_0^2} = \frac{g_0 m}{e}$$

If Q_0 is the total negative charge on the Earth, $\frac{Q_0}{r_0^2}$ is the potential-gradient X_0 at the Earth's surface,

$$\text{Hence} \quad \frac{Q}{Q_0} = \frac{g_0 m}{e X_0} = \text{about } 4 \times 10^{-13} \text{ for } X_0 = 150 \text{ volts/meter.}$$

quences of the view above discussed, it is not intended to propose it as a theory, since, apart from the arbitrary nature of the fundamental idea postulated, a theory on these lines does not lend itself very naturally to an explanation of the details of atmospheric-electric phenomena. If we were to adopt the view discussed above as to the origin of the Earth's negative charge, the most natural place to look for the source of the corpuscles is the Sun. There are many difficulties to be met with, however, in attributing effects of this kind to the Sun. A somewhat attractive view is to be found in adopting a theory somewhat analogous to Le Sage's theory of gravitation, and imagining that all space is filled with corpuscles flying about in all directions. We may then look upon the planets as centers of absorption of the corpuscles. We should on this view expect the rate of absorption of corpuscles and, consequently, the Earth-air current-density to be porportional to the surface of the planet, unless the corpuscles were so penetrating that an appreciable fraction of them passed through. It is to be observed, however, that a degree of penetration even sufficient to enable a corpuscle to pass through the Earth's atmosphere is greater than any we are acquainted with in laboratory experiments.

Let us now consider the hypotheses of the third type, referred to on page 109.

Requirements of the form of hypothesis of the third type, in which the replenishment of charges is confined to one region only at any one time. Suppose, to fix our ideas, that the replenishment is taking place over a region of the Earth's surface AB, Fig. 2. Even though in such a spot as C there might initially be a distribution of negative electricity, nevertheless this would disappear, in accordance with the argument on page 105, in a few minutes if negative electricity were not supplied from AB. If such supply does take place, however, an Earth-air current will continue to exist at C, and the increase of conductivity with the height above C will result in the amount of positive electricity in a column of the atmosphere of 1 sq. cm. cross section standing on that spot being equal to the amount of negative electricity per square centimeter of the Earth below. It will be necessary for the negative current from the regions like C to turn round in the upper atmosphere and travel back to the side $A\ B$. Unless the conductivity of the upper atmosphere is extremely great, it will turn out that the current density on the side C will be infinitesimal compared with that at $A\ B$, as may be seen from the following argument. Suppose, to

fix our ideas, that the positive electricity is deposited in the atmosphere over A B, in one layer E F somewhere in the upper atmosphere. Then the conditions are just such as we should have if A B and E F were two plates, and if, having attached them to the poles of a battery so as to keep them charged, we then joined

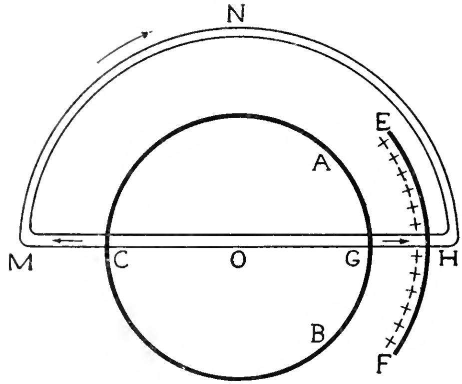

FIG. 2

them by two wires in parallel, one corresponding to the path from A B across to E F along such lines as G H, and the other corresponding to the path through the Earth, up through the atmosphere above points like C (which do not lie under E F) and back through the upper atmosphere, the path being indicated in a general sort of way by lines such as G O C M N H. The length of the path G O C M N H is of the order of magnitude of thousands of kilometers, while G H is only of the order of magnitude of 10 kilometers.

A consideration of the circumstances shows that the stream lines cannot widen out in the upper atmosphere in such a way as to compensate for the greater length. Thus, unless the conductivity of the upper atmosphere corresponding to such paths as M N H is very large indeed, so that the resistance of the whole of a tube of flow of the long path is only comparable with that of its part C M, the current along the tube of flow corresponding to the long path will be small compared with that along the corresponding tube such as G H; in other words, the current density in the atmosphere at points like C will be small compared with that at points like G. It is immediately obvious that under these conditions the potential-gradient at C will be small compared with that at G; A B and E F will, in fact, act more or less like a parallel plate condenser. Thus the existence of finite values for the po-

tential-gradient and vertical conduction current-density at those portions of the Earth like C depends on the assumption of a state of very high conductivity in the upper atmosphere.

In order to get a very rough idea of the conductivity which it is necessary to attribute to the upper atmosphere in order that the potential-gradient at a point like C shall be practically the same as that at G, suppose we assume that the length of the portion $M\,N\,H$ of a tube of flow is of the order of magnitude of half the circumference of the Earth—i. e., 2×10^4 kilometers—and that the height $C\,M$ is 10 kilometers. If the tubes of flow in the upper atmosphere had the same cross section as in the lower atmosphere, then, in order that the potential drop between C and M should be more than, say, 90 per cent of that between G and H, it would be necessary for $\frac{\lambda_l \times 2 \times 10^4}{\lambda_u \times 10}$ to be less than 0.1, λ_l and λ_u being the average conductivities for the paths $C\,M$ and $M\,N\,H$ respectively. Hence λ_u is greater than $2 \times 10^4 \lambda_l$. A consideration of the circumstances shows that the stream lines in the upper atmosphere would have to be more congested than in the lower atmosphere, hence λ_u would have to be greater than the above in the ratio of the approximate average cross-sectional areas of the stream lines. Calling the ratio η, if the effective thickness of the upper atmosphere is taken as 300 kilometers, it will be readily seen that the order of magnitude of η is the same as that of the ratio of the area of a hemisphere of the Earth to the cross-sectional area of an annulus whose inner radius is that of the Earth and whose outer radius exceeds this by 300 kilometers. Thus η is of the order of magnitude of $\frac{r}{2 \times 300}$ where r is the radius of the Earth in kilometers; i. e., $\frac{2}{\pi} \times 10^4$. Thus η is of the order of magnitude of $\frac{10^4}{300\pi} = 10$, say. If we take this value for η we have λ_u greater than $2 \times 10^5 \lambda_l$.

In spite of the very large value for λ_u, it is enormously smaller than the value which Schuster has found necessary to account for the explanation of the diurnal variations of the Earth's magnetism on the hypothesis of electrical circulations in the upper atmosphere brought about by air motion across the lines of magnetic force. The highest value recorded for the conductivity is that by Wigand[5], viz., 4×10^{-3} E. S. U. at an altitude of 9,000 meters. Since the

[5] Wissenschaftliche Hochfahrten im Freiballon. *Fortsch. der Naturwiss. Forsch.*, Bd. X, Heft. 6, 1914.

value of λ_l must certainly be less than this, we find that λ_u need not be greater than 800 E. S. U. Now, the value found by Schuster as necessary for the magnetic problem is 10^{-13} E. M. U.,[6] i. e., 9×10^7 E. S. U., a value about 10^5 as large as the value of λ_u above. Thus, if we are prepared to accept a value of the conductivity sufficiently large to fit the magnetic problem, we shall abundantly provide for the approximate equalization of the potential-gradient and Earth-air current over the Earth's surface (allowance of course being made for ordinary variation in conductivity, etc), even though the replenishment of the negative charge to the Earth and the positive charge to the atmosphere takes place at only one spot.

A cursory consideration of the problem might make it appear that above points like C the lines of flow would not be vertical, but would bend round on their way back to the side A B of the Earth. A moment's consideration will show, however, that the lines of flow will, apart from purely local influences, only begin to bend appreciably when they get to the regions where the conductivity is very high. In fact the path of least resistance through the atmosphere from C to the side A B is found by rising perpendicularly at C until the highly-conducting regions are reached, and then making the turn.

Although we have discussed the above matters for a case where the positive electricity is deposited, or makes its initial appearance in the atmosphere all at one level E F, it will be obvious on a little consideration that the essentials of the argument are not modified when we consider the case where the deposition appears at all levels. Remembering that E F was supposed to be located in the upper atmosphere, it will readily be seen that the effect of some of the positive electricity being deposited nearer to the Earth's surface than E F is to reduce the effective resistance of paths like G H in their relation to the corresponding long paths. The result is that even with infinite conductivity in the upper atmosphere we might not expect to get as much conduction current-density or potential-gradient at C as at G. This conclusion is by no means bound to follow, however, as will be seen more particularly in connection with the development of the consequences of a class of hypotheses considered in Part II. It will be best to leave the further

[6] Of course it is to be noted that in the problem discussed by Schuster this relatively high value of the conductivity is only required over the sunlit portion of the upper atmosphere. For the atmospheric-electric problem, a high value of the conductivity is necessitated over all portions of the upper atmosphere.

discussion of the matter, therefore, until it may be considered directly in connection with that development; in the meantime it is sufficient to remark that the difference between the values at *C* and *G* involved in this connection are entirely different from those which we should have if the conductivity of the upper atmosphere were of an order of magnitude anything like that of the lower atmosphere, for in this latter case we should have practically no potential-gradient at *C*.

It is to be noticed that a theory of the type at present under discussion would lead to a curious difference between the characteristics of the conduction current-density at *C* and *G*, for example. At *C*, in spite of the positive charge which would automatically appear in the atmosphere, the vertical conduction current-density would be independent of the altitude until altitudes were reached where the stream lines started to be deflected. On the other hand, as we rose above *G* the vertical conduction current-density would, at any rate in the simplest and most obvious cases,[7] continually diminish with altitude to zero if the replenishment of the positive to the atmosphere took place at all altitudes.

Most of the theories which have been proposed to account for the origin and maintenance of the Earth's negative charge provide for the replenishment at any given spot, only during a portion of the day, and so fall under the type above discussed. For the explanation of the existence of a potential-gradient and conduction current at a place during the hours when replenishment is not occurring at that place, they require the assumption of a state of very high conductivity in the upper atmosphere. This aspect of the matter does not appear to have been brought out in such theories, the difficulty with regard to the maintenance of a potential-gradient at all times and places though the replenishment is taking place only at one spot sometimes appears to be dismissed with the statement that the Earth is a conductor, and the charge distributes itself uniformly over the surface.

Discussion of various theories which have been proposed. Simpson's Theory. In a short note published in 1904,[8] G. C. Simpson suggested the possibility of explaining the maintenance of the electrical conditions in the atmosphere by assuming that positive and negative corpuscles were emitted from the Sun. These cor-

[7] This question will be more fully explained later in Part II.

[8] A theory of the cause of atmospheric electricity, *Nature*, vol. 69, No. 1786, Jan. 21, p. 270 (1904).

puscles were supposed to penetrate our atmosphere, and some of them were supposed to succeed in reaching the Earth. It was assumed that the positive corpuscles would be absorbed by the atmosphere more readily than the negative ones, so that the corpuscles reaching the Earth would be mainly negative. The Earth would thus charge up negatively until the conduction current back to the various parts of the atmosphere was sufficient to balance the effects due to the influx of the corpuscles. The theory is of the type we have just discussed, for unless we could imagine the corpuscles to be so turned by the Earth's lines of magnetic force that they struck the Earth with more or less uniform density, we should get practically no precipitation of corpuscles at night. Apart from the question of the possibility of a stream of negatively-electrified corpuscles reaching us from the Sun, it would seem that the theory would have taken a simpler aspect if the assumption of the precipitation of the positive corpuscles had been omitted. The explanation of the positive charge in the atmosphere would then have been thrown on to the fact that the conductivity increases to a high value at high altitudes, and the theory itself would in fact have reverted to the form of that cited on pages 110-111.

Precipitation Theory. A theory of the maintenance of the Earth's negative charge has been put forward by C. T. R. Wilson, on the lines that rain would be expected on the average to bring down more negative electricity than positive as a result of the greater facility with which the water vapor would condense on the negative ions. Apart from the fact that experiments do not appear to show that more negative electricity than positive is brought down, however, it has been shown by Simpson that the conditions of supersaturation necessary to cause the vapor to condense on the ions are never attained in the atmosphere.

Schuster has considered the question as to whether the charges brought down by lightning may account for the Earth's negative charge. The data in this respect are somewhat uncertain, but from a consideration of such data as exist, Schuster arrived at the conclusion that it is improbable that the lightning discharges can play an important part in increasing or diminishing the charge on the Earth.

With regard to any theory accounting for the replenishment of the charge by such phenomena as rain or lightning, which take place in isolated spots, the arguments on pages 105-106 apply to show that at places where the phenomena are temporarily absent

the potential-gradient would be expected to fall to zero unless a circulation could be set up of the kind discussed on pages 111-116, and in which the resistance of the "long paths" through the upper atmosphere were negligible. In the case of such theories as the precipitation theory, there will in general be several places of precipitation at any instant, so that the lengths of the long paths will not have to be as great as in the example cited on pages 111-116. On the other hand, they will have to comprise not only the extreme upper atmosphere, but will have to extend down to the altitudes of the rain clouds.

Theories of Elster and Geitel, and of Ebert. One of the earliest theories of atmospheric electricity and of the maintenance of the Earth's negative charge was put forward by Elster and Geitel. This theory was founded on an experiment made by Zeleny, in which a negative charge was obtained on a conducting tube by passing ionized air through it. The explanation of the experiment was taken to depend upon the greater mobility of the negative ions as compared with the positive ions. Applying this idea to the atmosphere, Elster and Geitel supposed that the Earth would charge up negatively until by its repulsive action it just counteracted the effect of the greater mobility of the negative ions. The difficulty associated with the fact that the corresponding positive ions would be expected to be within molecular distances of the Earth's surface is met by an appeal to convection currents and general air motion. Simpson, however, found that by passing ordinary atmospheric air through a tube it was impossible to get any charging effect other than that corresponding to the Volta effect, and concluded that such charging effect is only obtained when ionized air passes from a place of higher to one of lower ionization.

A modification of Elster and Geitel's theory has been proposed by Ebert, according to whom the negative charge on the Earth is due to the passage of the highly ionized air contained in the pores of the Earth out into the atmosphere during the period of fall of atmospheric pressure. It is supposed that, as in the experiment of Zeleny, the negative electricity will be deposited on the walls of the capillary pores. That a charging effect can be obtained in this way has, however, been denied by Simpson and Gerdien, on grounds of which a full discussion is given in several papers in the Physikalische Zeitschrift for 1904 and 1905. Even though the reality of the charging effect is admitted, it becomes necessary

to rely on convection to account for the passage of the positively charged ions to appreciable distances above the Earth in opposition to the potential-gradient. In fact if ρ is the density of positive electricity in the air and v is the resultant vertical convectional velocity, it is necessary that $\rho\, v$ shall be equal to the measured Earth-air current-density. In spite of the apparent simplicity of the test, the uncertainty in our knowledge of the proper value of v and, indeed, until recently, at any rate, of the proper value of ρ makes it difficult to say whether the convection current-density could or could not amount to the necessary value. Gerdien came to the conclusion that it would only amount to about three per cent of the necessary value, but more recent values of ρ as measured by Daunderer appear to show that at any rate near the Earth's surface the convection current-density can amount to a value of the same order of magnitude as the conduction current-density. A point which does not seem to have been realized in the discussion, however, is that, even though we admit the necessary value of ρ near the Earth's surface, it would be impossible for the positive electricity to travel very far above the Earth's surface before it became eaten up, as it were, by the action of the conductivity, in a manner which will be clear from the following considerations:

Possibility of a balance between the conduction and convection current-densities. Let us consider a quantity of air containing positive electricity, and surround any volume of it by a closed surface S. Let X_n be the electric force normal to S at any point, and let λ be the conductivity. If Q is the total quantity of positive electricity inside S at any time,

$$-\frac{dQ}{dt} = \int\!\!\int X_n \lambda \, ds$$

But, by Gauss' theorem $\int\!\!\int X_n \, ds = 4\pi Q$

Hence $$-\frac{dQ}{dt} = 4\pi\lambda Q$$

and if Q_0 is the initial value of Q

$$Q = Q_0 e^{-4\pi\lambda t} \tag{1}$$

By substituting in this expression a value of λ appropriate to the air (say $\lambda = 3 \times 10^{-4}$ E. S. U.), we find that only about 10 minutes is required for Q to become reduced from Q_0 to $\frac{1}{10} Q_0$. The argument is not limited to the case where the volume of air is stationary, and it is of interest to observe that the rate of loss of

charge from S is totally determined by the charge inside S, and has nothing to do with the charge outside. Thus a mass of charged air which was rising would, during the process, lose its charge at such a rate that before it had risen very far there would be but little charge left. A little consideration will show that the positive charge becomes lost at the expense of the ordinary conduction current (which corresponds to an upward flow of negative electricity), so that the conduction current-density should diminish with altitude and should reach practically a zero value at an altitude equal to that at which the positive charge in the rising air has reached a practically zero value. As remarked above, Q would be reduced to one-tenth of its initial value in 10 minutes for a value of λ equal to 3×10^{-4} E. S. U. During this time the air would only have traveled 600 meters if it had moved with a velocity of as much as one meter per second. We should consequently expect that the vertical conduction current-density would have diminished at this altitude to about 10 per cent of its value at the Earth's surface, a result not consistent with the facts of balloon experiments, which show no very marked diminution of the vertical conduction current at altitudes of several kilometers. Though in the above argument we have for simplicity and for the purpose of accentuating the fundamental process at work assumed that λ is constant all over the surface S, it is to be realized that in practice this is not the case. If λ is not constant, the argument will be modified, as is obvious from the fact that when the conductivity increases with the altitude, the field itself brings about a condition of affairs in which the air is positively charged. The mechanism of the phenomenon in this case is, however, of the same general type as that of the simple case above referred to, though it is better to put the argument in a slightly different mathematical form.

Thus, if X represents the potential-gradient at any distance x above the ground, and if ρ is the density of positive electricity in the atmosphere, the density being supposed constant in horizontal layers; and if v is the upward velocity of the air, we must, in the steady state, have the algebraical sum of the conduction and convection current-densities equal to zero. Thus

$$\rho v - X\lambda = 0 \tag{2}$$

Again, if we consider two horizontal planes separated by a distance dx, then, in the steady state, the net quantity of electricity flowing into this layer as a result of the air motion must be equal to the

4

net quantity flowing out of it as a result of the difference between the electrical current-densities on the upper and lower planes. Thus,

$$\frac{d\,(\rho v)}{dx} = -4\pi\lambda\rho$$

Hence if the subscript o refers to the Earth's surface,

$$\rho v = \rho_0 v_0 e^{-\int_0^h 4\pi \frac{\lambda}{v} dx} \tag{3}$$

where h refers to the altitudes at which we are considering the effects. Thus, from (2) and (3)

$$X\lambda = X_0 \lambda_0 e^{\int_0^h 4\pi \frac{\lambda}{v} dx} \tag{4}$$

Now since λ increases with the altitude, and v decreases, we have $X\lambda$ certainly less than the value obtained by substituting $\frac{\lambda_0}{v_0}$ for $\frac{\lambda}{v}$ in (4).

$$\text{Hence} \quad \frac{X\lambda}{X_0\lambda_0} < e^{-4\pi\frac{\lambda_0}{v_0}h} \tag{5}$$

If $\lambda_0 = 3 \times 10^{-4}$ E. S. U., and $v_0 = 100$ cm/sec, and if we put $h =$ 1000 meters, we find

$$e^{-4\pi\frac{\lambda_0}{v_0}h} = 0.02$$

$$\text{Hence} \quad \frac{X\lambda}{X_0\lambda_0} < 0.02 \tag{6}$$

Thus $X\lambda$, which represents the conduction current density at the altitude 1,000 meters, would be less than 2 per cent of $X_0\lambda_0$, which represents the conduction current-density at the Earth's surface.

Again from (6)

$$\frac{X}{X_0} < 0.02\,\frac{\lambda_0}{\lambda}$$

From balloon observations it appears that for an altitude of 1,000 meters, $\frac{\lambda_0}{\lambda}$ is about 0.4. Hence, at this altitude we should have X less than one per cent of its value at the Earth's surface.

The physical explanation of the above is of course that with in-

crease of altitude the positive charge in the rising air becomes eaten up more and more. It disappears at the expense of the conduction current, and both the conduction current-density and the potential-gradient become practically zero at an altitude at which ρ has become sensibly zero.

Now we know that the potential-gradient and conduction current extend to far greater heights than 1,000 meters. The potential-gradient still amounts to about 3 volts per meter at 9,000 meters, and at a height of 1,000 meters, according to the measurements of Wigand, its value is more than 50 per cent of that at the Earth's surface. According to the same measurements, the conduction current-density is as great, or even greater, than the value at the Earth's surface. Thus, quite apart from the difficulty of explaining the origin of a continual supply of positive electricity to the atmosphere at the ground level, it would seem that the convection of such electricity by the upward air motion could not account for the phenomena required of it. This objection applies not only to the theories of Elster and Geitel, but to any theory in which an attempt is made to explain the phenomena by supposing the convection current to balance the conduction current.

It is interesting to recall in this connection that Daunderer, by measurements made near the Earth's surface, has found very much larger values for the charge-density in the atmosphere than those deduced from balloon observations. It is probable that the explanation of this phenomenon is intimately related to the above considerations.

The question of the rapid disappearance of a positive charge in the atmosphere when left to itself has an interesting bearing in a slightly different connection. As Simpson has pointed out, there is difficulty in making the Ebert theory account for a potential-gradient over the sea, since, as the results of many investigators have shown, there is very little radioactive material in sea water; and even if there were, the phenomenon of the emanation being drawn out of the pores of the Earth could have no counterpart on the ocean. The difficulty has been met by Ebert by the statement that some of the positive charge in the air over the land becomes blown over the sea, so that the conductivity of the sea water is then all that is necessary to insure that the potential-gradient and the atmospheric positive charge shall extend itself over the sea. It would not appear, however, that the difficulty can be avoided in this way, because, as shown by the calculation on page 119, posi-

tively charged air would lose 90 per cent of its charge in 10 minutes during its journey, so that the amount left by the time the air had reached the central parts of the great oceans would be insignificant. If the positive charge were absent from the air over the sea the potential-gradient would also be absent there, for, although the whole of the Earth is at the same potential, the whole of the charge on its surface will be held bound in those regions where there is positive charge in the atmosphere.

Significance of the conduction of electricity from an earthed plate. A further objection may be raised against any theory such as Elster and Geitel's, according to which the separation of charges arises as the result of a surface effect. In the case of the Elster and Geitel theory, for example, if we consider a plane on the Earth's surface, say 1 millimeter thick, the loss of negative electricity from this plane owing to the conduction current would just be balanced by the gain from the atmosphere owing to the supposed diffusion phenomenon. Thus, if a plate were insulated at the ground level and were initially at zero potential, it would be expected to lose no charge. In practice, however, it is found that such a plate does lose a charge, and the Earth-air current-density as calculated in this way appears to be equal to the Earth-air current-density as derived from the atmospheric conductivity and potential-gradient. This necessitates that the replenishment of the negative charge to the surface of the Earth takes place, at any rate directly, by a flow of electricity to the surface from inside. As to how the negative gets inside is another matter with which we shall deal further in Part II.

The variation of the vertical conduction current-density with altitude. Perhaps there is no atmospheric-electric element which seems more likely to be fruitful in guiding our choice of a theory than that of the variation of the conduction current with altitude. We have already seen on page 121 how the nature of this variation is such as to present a very serious objection to any theory in which the conduction current is balanced by an ordinary convection-current. Under ordinary conditions, as explained on pp. 106-107, if the only way by which electricity can enter or leave the elements of volume of the atmosphere is by conduction, then in the steady state the vertical conduction current-density must be independent of the altitude. Conversely, if a steady state is attained in which the vertical conduction current-density is not independent of the altitude, we are forced to conclude that electricity

is entering or leaving the volume elements partly by a process, or by processes, other than conduction.

Suppose that conduction is alone acting, but that the atmosphere has by some means been altered from the steady state which would prevail under these conditions, and let us calculate the rate of approach to the steady state. We shall find that it is very rapid, for let the field be maintained constant at the value X_0 on the Earth's surface, or preferably over some specified plane the distance of which, above the surface, is sufficiently great to render convection negligible at still greater altitudes. Let h be the altitude of a point above this plane, σ the net quantity of positive electricity contained in a column of the air of cross section 1 sq. cm., and extending down from the point to the plane. The equation of continuity as applied to the column referred to gives

$$\frac{d\sigma}{dt} = X\lambda - X_0\lambda_0$$

Since $X = X_0 - 4\pi\sigma$

$$\frac{d\sigma}{dt} + 4\pi\sigma\lambda = X_0(\lambda - \lambda_0) \tag{7}$$

Now if σ, is the value of σ corresponding to the steady state and for the same value of X_0, we have

$$(X_0 - 4\pi\sigma_1)\lambda = X_0\lambda_0 \tag{8}$$

Hence, from (7) and (8)

$$\frac{d\sigma}{dt} + 4\pi\lambda(\sigma - \sigma_1) = 0$$

Hence, if s is the excess of the value of σ over the value corresponding to the steady state

$$\frac{ds}{dt} + 4\pi\lambda s = 0$$

$$s = s_0 e^{-4\pi\lambda t} \tag{9}$$

where s_0 is the initial value of this excess.

In so far as s is proportional to the excess of the potential-gradient at the altitude considered over the value at that altitude in the steady state, we see that this excess will fall to one-tenth of its initial value in a time given by $4\pi\lambda t = -\log_e(0.1)$, λ being the value of the conductivity at the altitude concerned. The time in question will certainly be less than the value obtained by putting $\lambda = \lambda_0$ in the above formula, so that if $\lambda_0 = 3 \times 10^{-4}$ E. S. U., we find t smaller than 10 minutes.

Since the conduction current-density at any altitude is proportional to the potential-gradient there, a conclusion exactly similar to the above results for it.

We can also see from (9) that for any column the value of s will fall to one-tenth of its initial value in less than 10 minutes. Again, since $\frac{d\,s}{d\,h}$ represents the excess of the density of the charge at any point over the value corresponding to the steady state, we see that if $\Delta\,\rho$ corresponds to this excess density,

$$\Delta\rho = e^{-4\pi\lambda t}\left\{\Delta\rho_0 - 4\pi\, s_0\, t\,\frac{d\lambda}{dh}\right\}.$$

Since $\frac{d\,\lambda}{d\,h}$ is positive, it is obvious that the time taken for $\Delta\,\rho$ to reach any fraction of its initial value is less than the time given by

$$\Delta\,\rho = \Delta\,\rho_0\, e^{-4\pi\lambda t}$$

Hence even if we use the minimum value for λ, say $\lambda = 3 \times 10^{-4}$, we find that the time taken by $\Delta\,\rho$ in sinking to one-tenth of its initial value is less than 10 minutes.

It is thus clear from the above considerations that the only way of accounting for a permanent state other than that of constancy of conduction current-density with altitude is to assume that electricity enters or leaves the volume elements partly by some process other than conduction; further, unless such an assumption is made, any temporary departure from the condition of constancy of the conduction current-density will tend rapidly to disappear.

One reservation must be made on the above remarks. If the conductivity at different altitudes is continually altering, or if the part of the potential-gradient which depends on charges not contained in the portion of the atmosphere above the plane referred to is continually varying, it is possible to have a departure from the condition of constancy of the conduction current-density while such alteration is in progress. The rates of alteration of the elements corresponding to the diurnal variations are so slow, however, that they are not of a type to be of influence in this respect. So quickly does the atmosphere get into the steady state corresponding to any given value of the above portion of the potential-gradient, and any given distribution of conductivity, that only with the spasmodic fluctuation in these quantities is it unable to keep pace. Such spasmodic fluctuations are as likely to be in one direction as

another, and consequently are not of a type to serve as the explanation of any regular departure from the condition of constancy of the conduction current-density with altitude.

The results of balloon experiments indicate very marked departures from the condition of constancy of conduction current-density with altitude, and this is the case, moreover, at altitudes so great that it is difficult to see how any explanation can be sought from an appeal to convection currents, especially when we take into account the arguments on pages 119-122. It is true that the results of balloon experiments are not very concordant, and, further, the measurements at different altitudes have necessarily to be taken at different times of the day, but, on the other hand, the results indicate variations of the conduction current-density amounting to 100 per cent or more of the smaller values. In Part II a more detailed consideration of the results of balloon experiments will be given, more particularly in connection with the developments of the results of a class of hypotheses formulated to provide for electricity entering or leaving the volume elements by a process other than that of conduction.

Summary.

(1). After pointing out that the charge on the Earth would disappear very quickly if there were no means of replenishment, it is shown that if such replenishment is provided the mere fact of the increase of conductivity with altitude to a high value is sufficient to account for the existence of the positive charge in the atmosphere.

(2). It is shown that electromotive forces necessary to provide for a general electrical circulation in the atmosphere are much greater than can be accounted for from electro-dynamical effects.

(3). The general possible types of theory are considered, and it is shown that on any theory in which the replenishment of charge to the Earth and atmosphere is confined to one place at one time the potential-gradient at other places would be insignificant unless a state of very high conductivity existed in the upper atmosphere.

(4). A brief discussion is given of various theories so far proposed. In connection with the theories of Elster and Geitel, and of Ebert, it is shown that, quite apart from the question of whether the vertical convection current-density can have a magnitude sufficiently great to balance the conduction current-density, any theory relying on such an assumption must lead to the conclusion

that the conduction current-density and the potential-gradient become zero at a comparatively small altitude. It is further shown that no theory which attempts to account for the existence of a potential gradient over the sea by the assumption that positively charged air is blown out from the land is tenable.

(5). A discussion is given as to the possibility of variation of the vertical conduction current-density with altitude. It is pointed out that the permanent existence of such a state of affairs necessitates that electricity passes into or out of the volume elements of air partly by processes other than conduction. It is further shown that in the absence of such processes, if the atmosphere is disturbed from the state in which the conduction current-density is independent of the altitude, it will very rapidly revert to that state again.

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THE MEAN VALUE OF A FUNCTION OF SPHERICAL POLAR COORDINATES ROUND A CIRCLE ON A SPHERE.

By H. Bateman.

Some years ago von Bezold[1] pointed out that the mean value of the magnetic potential round a parallel of geographical latitude is very nearly equal to a constant multiple of the cosine of the north polar distance. Shortly afterward Adolf Schmidt[2] considered the problem of finding the diameter of the Earth for which the mean value of the magnetic potential round each small circle with the diameter as axis, approximates in the best way to a constant multiple of the cosine of the polar distance from one extremity of the diameter. Schmidt chose as the criterion for obtaining the best approximation the condition that the square of the difference between the two quantities just mentioned, when integrated over the whole Earth, should be a minimum.

While reading Schmidt's paper, in connection with some studies at the Department of Terrestrial Magnetism during the past summer, it occurred to me that it might be useful to have a simple formula for the mean value of a function round a circle on a sphere. Such a formula can be deduced without much trouble from the formulæ for the transformation of spherical harmonics in a transition from one set of polar coordinates to another. These formulæ have been given by Adolf Schmidt,[3] but the particular theorem we are interested in is not explicitly mentioned in his paper. A more direct proof of the theorem may be obtained by using a certain property of potential functions, and is perhaps worth recording.

Let a function $F(\theta, \phi)$ of the spherical polar coordinates θ, ϕ be expanded in a series of spherical harmonics

$$F(\theta, \phi) = S_0 + S_1(\theta, \phi) + S_2(\theta, \phi) + \ldots + S_n(\theta, \phi) + \ldots \qquad (1)$$

which for simplicity we shall suppose to be absolutely convergent. In this equation S_0 is a constant and, with the usual notation, S_n denotes an expression of type

$$S_n = a_{no} P_n(\cos\theta) + \sum_{m=1}^{n} (a_{nm} \cos m\phi + b_{nm} \sin m\phi)\, P_n^m(\cos\theta) \qquad (2)$$

where the a's and b's are constants.

[1] *Sitzungs-Berichte der Akademie der Wissenschaften zu Berlin*, math.-phys. Classe, (1895), pp. 363-378.

[2] *Terr. Mag.*, vol. I (1896), p. 18.

[3] *Zeitschrift für Mathematik und Physik*, Bd. 44, (1899), p. 327.

If r is the distance of a point from the center of a sphere of radius unity, the potential function

$$V = S_0 + r S_1(\theta, \phi) + r^2 S_2(\theta, \phi) + \ldots + r^n S_n(\theta, \phi) + \ldots \qquad (3)$$

will take the value $F(\theta, \phi)$ at points on the sphere $r = 1$, and so the mean value of F round a circle on the sphere is equal to the mean value of V.

Now, the mean value of such a potential function round a circle can be expressed in terms of the values of the potential function on the axis of the circle.[4] If $V = f(r)$ on this axis, the theorem states that the mean value of V is

$$\overline{V} = \frac{1}{\pi}\int_0^\pi f(\cos\alpha + i\sin\alpha\cos\psi)\, d\psi \qquad (4)$$

where α is the angle which the radius of the circle subtends at the center of the sphere.

Now let (θ_0, ϕ_0) be the polar coordinates of that pole of the circle for which α is the polar distance, then

$$\begin{aligned} f(r) = S_0 + r S_1(\theta_0, \phi_0) + r^2 S_2(\theta_0, \phi_0) + \ldots \\ + r^n S_n(\theta_0, \phi_0) + \ldots \end{aligned} \qquad (5)$$

Substituting in (4) we find, with the aid of Laplace's formula,

$$P_n(\cos\alpha) = \frac{1}{\pi}\int_0^\pi (\cos\alpha + i\sin\alpha\cos\psi)^n\, d\psi \qquad (6)$$

that

$$\begin{aligned} \overline{V} = S_0 + P_1(\cos\alpha) S_1(\theta_0, \phi_0) + P_2(\cos\alpha) S_2(\theta_0, \phi_0) + \ldots \\ + P_n(\cos\alpha) S_n(\theta_0, \phi_0) + \ldots \end{aligned} \qquad (7)$$

This is the required expression for the mean value of F.

The theorem relating to the mean value of the potential function may be proved very easily by taking the axis of the circle as the diameter through the pole of the coordinates (θ, ϕ). The mean value of V round the circle for which $\theta = \alpha$ is then

$$\overline{V} = a_{00} + a_{10} P_1(\cos\alpha) + \ldots + a_{no} P_n(\cos\alpha) + \ldots \qquad (8)$$

as is seen at once from (2). On the other hand, for points on the axis we have

$$V = f(r) = a_{00} + a_{10} r + a_{20} r^2 + \ldots + a_{no} r^n + \ldots \qquad (9)$$

Equation (4) is now an immediate consequence of equation (6).

Formula (7) may perhaps be of some use for the purpose of separating the harmonics of different degrees when a function

[4] *American Journal of Mathematics*, (1912), p. 335.

can be represented with considerable accuracy by a series containing only a limited number of terms. Let us suppose, for instance, that a function F can be represented by a series of four terms,

$$F(\theta, \phi) = S_0 + S_1 + S_2 + S_3 \tag{10}$$

the form being indicated by theoretical considerations but the coefficients in S_0, S_1, S_2, S_3 being unknown. Let us suppose, moreover, that the different curves along which F is constant have been drawn on the sphere, but that the function F is unknown.

If now we are provided with a circular wire whose radius is such that when the wire touches the sphere round a circle the corresponding value of α satisfies the equation P_3 $(\cos \alpha) = 0$, the mean value of F round this circle is

$$\bar{F}(\theta_0, \phi_0) = S_0 + P_1(\cos\alpha)\, S_1(\theta_0, \phi_0) + P_2(\cos\alpha)\, S_2(\theta_0, \phi_0) \tag{11}$$

Let this value be associated with the pole of the circle, viz, the point (θ_0, ϕ_0); the value associated with the diametrically opposite point may be found from another position of the wire and is

$$\bar{F}(\pi - \theta_0, \pi + \phi_0) = S_0 - P_1(\cos\alpha)\, S_1(\theta_0, \phi_0) + P_2(\cos\alpha)\, S_2(\theta_0, \phi_0) \tag{12}$$

Subtracting, we obtain

$$\bar{F}(\theta_0, \phi_0) - \bar{F}(\pi - \theta_0, \pi + \phi_0) = 2\, P_1(\cos\alpha)\, S_1(\theta_0, \phi_0) \tag{13}$$

whence S_1 is determined. By addition we may obtain the value of $S_0 + P_2 S_2$. Now use a wire whose radius corresponds to a value of α for which P_2 $(\cos \alpha) = 0$; the mean value of $S_0 + P_2 S_2$ round such a circle on the sphere is then S_0. The values of S_0, S_2 and finally S_3 may then be found.

In calculating the mean value of F round a circle, it is sufficient to take the mean of the values at the vertices of a regular polygon whose sides are more than twice as numerous as the terms of different degree in the series representing F. Thus in the case under consideration we can use a regular octagon. The method sketched here is not intended to supersede the standard methods of spherical harmonic analysis[5], for it is inferior to them in many respects. It is mentioned here simply as a method which, with suitable apparatus, could be carried out fairly quickly by anyone desiring to use only the simplest mathematical operations.

[5] These are (1) the well-known method in which the coefficients are determined as integrals taken over the surface of a sphere, (2) the method suggested by F. E. Neumann in 1838 (cf. *Math. Ann.*, Bd. 14 (1879), p. 567, and used by Ad. Schmidt, *Archiv der Deutschen Seewarte* (1889), and (3) the method proposed by A. Schuster in 1902, *Phil. Trans.* A., vol. 200, p. 181. When the function V is actually given as a polynomial of the n^{th} degree in x, y, z, the present problem may be solved with the aid of Laplace's operator ∇^2 by a well known method due to Gauss.

BIOGRAPHICAL SKETCH OF FRIEDRICH BIDLINGMAIER.

Among the early victims of the present unfortunate European war was our lamented colleague, Professor Dr. Friedrich Bidlingmaier, who lost his life on September 23, 1914, in the battle of Verdun, at the age of 39 years.

Born at Lauffen, on the Neckar, on October 5, 1875, he obtained his early education at Maulbronn and Blaubeuren, and from 1894-1898 pursued studies in mathematics and physics at the universities of Tübingen and Göttingen. During the period 1898-1900 he was assistant in the Physical Institute of the "Technische Hochschule" in Dresden.

In May 1900 he joined the staff, as magnetician, of the German Antartic Expedition 1901-1903, under the leadership of Professor von Drygalski. The various publications relating to the magnetic work of this expedition furnish the best possible testimony of the enthusiasm, zeal, and ability displayed by Bidlingmaier. Handicapped as he was by lack of certain instrumental appliances, and being obliged also to contend with the difficulties inherent when ocean magnetic observations must be made on a vessel not wholly designed for the purpose, it is not to his discredit that he at times was unable to reach the degree of accuracy which he had set for himself. Apparently fully recognizing this, he sought, with splendid success, by theoretical and experimental investigations, to make the contributions to terrestrial magnetism of the German Antarctic Expedition noteworthy ones. It is unfortunate that, for one reason or another, publication was at times so much delayed that others were obliged to go over somewhat the same ground.

In 1907 he was privat docent in geophysics at the University of Berlin; in 1908 he occupied a similar post at the "Technische Hochschule" in Aachen, where he was also assistant in Professor Haussmann's institute. At the Wilhelmshaven naval observatory, to which he received a call in the fall of 1909, his "magnetic activity" began to display itself once more. After a sojourn here of 3 years, he was appointed, in 1912, "Kustos" of the Munich magnetic observatory, in succession to the deceased Messerschmitt. His various publications during these years 1909-'14 amply testify to his versatility, his insight, and his deep love for investigation and the truth.

He was married in October 1906 to Miss Edith Ideler, daughter of Pastor Ideler. His unpublished manuscripts and data relating to the German Antarctic Expedition have been taken in charge by Professor von Drygalski.

L. A. B.

LATEST ANNUAL VALUES OF THE MAGNETIC ELEMENTS AT OBSERVATORIES.[1]

COMPILED BY J. A. FLEMING AND W. F. WALLIS.

Observatory	Latitude	Longitude	Year	Declination (D)	Inclination (I)	Intensity (C. G. S. units)	
						Hor'l	Vert'l
	° ′	° ′		° ′	° ′		
Pavlovsk	59 41 N	30 29 E	1907	1 09.9 E	70 37.7 N	.16503	.46937
Sitka	57 03 N	135 20 W	1909	30 13.1 E	74 34.6 N	.15576	.56462
			1910	30 16.4 E	74 32.2 N	.15593	.56368
			1911	30 19.1 E	74 30.4 N	.15606	.56298
			1912	30 20.9 E	74 28.8 N	.15615	.56231
Ekaterinburg	57 03 N	60 38 E	1907	10 35.5 E	70 52.2 N	.17623	.50806
Rude Skov	55 51 N	12 27 E	1910	9 28.7 W	68 45.0 N	.17375	.44680
			1911	9 20.4 W	68 44.8 N	.17359	.44631
			1912	9 12.2 W	68 45.4 N	.17342	.44610
			1913	9 03.5 W	68 46.6 N	.17319	.44597
Eskdalemuir	55 19 N	3 12 W	1911	18 12.4 W	69 37.1 N	.16846	.45344
			1912	18 03.9 W	69 37.2 N	.16846	.45345
Stonyhurst	53 51 N	2 28 W	1911	17 13.3 W	68 41.4 N	.17412	.44637
			1912	17 03.6 W	68 41.4 N	.17397	.44601
			1913	16 55.4 W	68 41.2 N	.17374	.44532
			1914	16 46.8 W	68 39.6 N	.17353	.44416
Wilhelmshaven	53 32 N	8 09 E	1910	11 37.0 W	67 30.5 N	.18124	.43773
			1911	11 28.2 W	67 30.7 N[2]	.18110	.43747[3]
Potsdam	52 23 N	13 04 E	1911	8 54.8 W	66 20.0 N	.18816	.42930
			1912	8 45.9 W	66 20.4 N	.18803	.42916
			1913	8 36.4 W	66 21.4 N	.18783	.42904
			1914	8 26.6 W	66 22.9 N	.18760	.42900
Seddin[4]	52 17 N	13 01 E	1910	9 04.3 W	66 16.6 N	.18866	.42933
			1911	8 55.8 W	66 17.0 N	.18853	.42916
			1912	8 47.2 W	66 17.4 N	.18841	.42899
			1913	8 37.9 W	66 18.4 N	.18822	.42891
			1914	8 27.9 W	66 19.9 N	.18798	.42885
Irkutsk	52 16 N	104 16 E	1905	1 58.1 E	70 25.0 N	.20011	.56250
De Bilt	52 06 N	5 11 E	1910	12 58.2 W	66 46.5 N	.18541	.43208
			1911	12 50.7 W	66 45.4 N	.18540	.43167
			1912	12 41.7 W	66 46.5 N[5]	.18537	.43200[5]
			1913	12 32.1 W	66 46.4 N	.18519	.43151

[1] From compilations by Dr. Charles Chree in British Meteorological and Magnetic Year Book for 1912, part IV, section 2, with additions by Jno. A. Fleming and W. F. Wallis, Department of Terrestrial Magnetism, Carnegie Institution of Washington. See tables for previous years in *Terr. Mag.*, vol. 4, p. 135; vol. 5, p. 128; vol. 8, p. 7; vol. 12, p. 175; and vol. 16, p. 209.

[2] Absolute measures only. [3] Computed from *I* and *H;* the same remark applies whenever the published observatory values are lacking. [4] 1910 values slightly corrected.

[5] Schulze earth inductor substituted for dip circle No. 61 in 1912. According to W. Kühl's comparisons at De Bilt in June, 1910 (*Veröff. Met. Inst.*, No. 229, 1911, pp. 150-159), to refer values of *I* observed with dip circle No. 61 to the Schulze earth inductor, add about +1.′8.

Observatory	Latitude	Longitude	Year	Declination (D)	Inclination (I)	Intensity (C. G. S. units)	
						Hor'l	Vert'l
	° ′	° ′		° ′	° ′		
Valencia...	51 56 N	10 15 W	1911	20 38.1 W	68 12.1 N	.17889	.44730
			1912	20 29.3 W	68 10.3 N	.17898	.44684
Clausthal..	51 48 N	10 20 E	1905	10 40.3 W	....	......	......
Bochum...	51 29 N	7 14 E	1909	12 04.1 W	....	......	......
			1910	11 56.4 W	....	......	......
			1911	11 48.3 W	....	......	......
			1912	11 39.4 W	....	......	......
Kew......	51 28 N	0 19 W	1911	15 55.3 W	66 57.2 N	.18502	.43490
			1912	15 46.5 W	66 56.5 N	.18498	.43454
Greenwich.	51 28 N	0 00	1910	15 41.2 W	66 52.6 N	.18552[6]	.43445
			1911	15 33.0 W	66 52.1 N	.18549[6]	.43421
			1912	15 24.3 W	66 51.8 N	.18548[6]	.43408
			1913	15 15.2 W	66 50.4 N	.18534[6]	.43327
			1914	15 06.3 W	66 49.4 N	.18518	.43254
			1914	....	66 51.2 N[7]	......	.43335[7]
Uccle.....	50 48 N	4 21 E	1910	13 22.2 W	66 00.8 N	.19028	.42764
			1911	13 13.9 W	66 00.1 N	.19025	.42734
Hermsdorf.	50 46 N	16 14 E	1910	7 23.9 W	....	......	......
			1911	7 15.5 W	....	......	......
			1912	7 06.9 W	....	......	......
			1913	6 58.2 W	....	......	......
Beuthen...	50 21 N	18 55 E	1908	6 12.3 W	....	......	......
Falmouth..	50 09 N	5 05 W	1911	17 33.0 W	66 28.2 N	.18798	.43172
			1912	17 24.2 W	66 26.6 N	.18799	.43118
Prague....	50 05 N	14 25 E	1910	8 09.6 W	....	......	......
			1911	7 59.3 W	....	......	......
			1912	7 50.3 W	....	......	......
Cracow....	50 04 N	19 58 E	1911	5 18.1 W	64 15.5 N	......	......
			1912	5 13.4 W	64 10.7 N	......	......
St. Helier (Jersey).	49 12 N	2 05 W	1907	16 27.4 W	65 34.5 N	......	......
Val Joyeux	48 49 N	2 01 E	1910	14 25.7 W	64 43.0 N	.19738	.41788
			1911	14 17.6 W	64 41.6 N	.19744	.41757
			1912	14 08.9 W	64 40.1 N	.19747	.41714
Munich....	48 09 N	11 37 E	1909	9 39.9 W	63 06.6 N	.20631	.40684
			1910	9 31.5 W	63 08.4 N	.20639	.40751

[6] According to *Nature*, June 10, 1915, p. 409, these values have been increased by 20γ because of a redetermination of the moment of inertia of the deflection magnet; corresponding corrections were made for the vertical intensity.

[7] Earth inductor.

Observatory	Latitude	Longitude	Year	Declination (D)	Inclination (I)	Intensity (C. G. S. units)	
						Hor'l	Vert'l
	° ′	° ′		° ′	° ′		
Kremsmünster[8]	48 03 N	14 08 E	1904	9 02.4 W	....	....	....
O'Gyalla (Pesth)..	47 53 N	18 12 E	1911	6 25.6 W	....	.21067	....
			1912	6 17.5 W	....	.21064	....
Odessa....	46 26 N	30 46 E	1910	3 35.9 W	62 26.9 N	.21707	.41605
Pola......	44 52 N	13 51 E	1910	8 28.0 W	60 04.7 N	.22194	.38562
			1911	8 17.5 W	60 03.6 N	.22190	.38526
			1912	8 08.5 W	60 03.6 N	.22199	.38544
			1913	7 58.1 W	60 03.6 N	.22200	.38544
Agincourt (Toronto)	43 47 N	79 16 W	1910	6 03.9 W	74 38.5 N	.16268	.59228
			1911	6 09.0 W	74 39.1 N	.16204	.59036
			1912	6 13.7 W	74 39.8 N	.16178	.58988
			1913	6 18.4 W	74 40.8 N	.16131	.58884
Perpignan.	42 42 N	2 53 E	1909	12 52.0 W	....	....	....
			1910	12 44.8 W	....	....	....
Tiflis......	41 43 N	44 48 E	1905	2 41.6 E	56 02.8 N	.25451	.37799
Capodimonte...	40 52 N	14 15 E	1905	8 45.3 E	56 15.0 N	.24165	.36165
			1906	8 40.3 E	56 13.5 N	.24167	.36134
			1907	....	56 13.1 N	.24146	.36054
			1908	....	56 13.0 N	.24153	.36102
			1909	....	56 14.4 N	.24129	.36098
			1910	....	56 11.9 N	....	....
			1911	....	56 11.7 N	....	....
Ebro (Tortosa)	40 49 N	0 31 E	1910	13 25.9 W	57 57.3 N	.23251	.37145
			1911	13 18.6 W	57 54.8 N	.23256	.37092
			1912	13 09.3 W	57 51.8 N	.23271	.37042
			1913	13 00.7 W	57 49.3 N	.23288	.37011
Coimbra...	40 12 N	8 25 W	1909	16 40.5 W	58 54.1 N	.22959	.38063
			1910	16 34.5 W	58 50.1 N	.22986	.38006
			1911	16 27.4 W	58 46.4 N	.23008	.37950
			1912	16 19.7 W	58 42.0 N	.23033	.37886
Cheltenham..	38 44 N	76 50 W	1909	5 36.4 W	70 32.8 N	.19883	.56294
			1910	5 41.4 W	70 35.4 N	.19826	.56264
			1911	5 45.6 W	70 37.4 N	.19765	.56197
			1912	5 50.0 W	70 39.1 N	.19702	.56108
Athens[9]...	37 59 N	23 42 E	1908	4 53.0 W	52 11.7 N	.26197	.33613
San Fernando[10]..	36 28 N	6 12 W	1910	15 13.6 W	54 38.1 N	.24879	.35053
			1911	15 05.2 W	54 31.5 N	.24894	.34932
			1912	14 54.3 W	54 26.7 N	.24923	.34870
			1913	14 51.7 W	54 26.6 N	.24939	.34890

[8] Three direct readings daily. [9] Electric car disturbances. [10] Absolute *I* observations for 1910-1913.

Observatory	Latitude	Longitude	Year	Declination (D)	Inclination (I)	Intensity (C. G. S. units)	
						Hor'l	Vert'l
	° ′	° ′		° ′	° ′		
Tokio	35 41 N	139 45 E	1910	4 58.2 W	49 07.3 N	.30007	.34668
			1911	5 00.6 W	49 05.0 N	.30025	.34640
Tucson	32 15 N	110 50 W	1910	13 25.8 E	59 19.6 N	.27406	.46206
			1911	13 29.7 E	59 19.9 N	.27370	.46155
			1912	13 33.5 E	59 20.3 N	.27331	.46101
Lukiapang[11]	31 19 N	121 02 E	1908	2 58.3 W	45 35.1 N	.33215	.33881
Dehra Dun	30 19 N	78 03 E	1909	2 34.8 E	43 48.0 N	.33276	.31909
			1910	2 31.9 E	43 54.8 N	.33257	.32019
			1911	2 29.2 E	44 02.0 N	.33238	.32136
			1912	2 25.9 E	44 08.9 N	.33218	.32244
Helwan	29 52 N	31 20 E	1911	2 33.2 W	40 41.9 N	.30030	.25828
			1912	2 25.4 W	40 43.7 N	.30063	.25884
			1913	2 17.0 W	40 47.6 N	.30031	.25916
Barrackpore	22 46 N	88 22 E	1909	1 00.7 E	30 38.7 N	.37300	.22099
			1910	0 55.5 E	30 42.2 N	.37329	.22168
			1911	0 49.9 E	30 45.5 N	.37337	.21220
			1912	0 44.0 E	30 50.7 N	.37369	.21316
Hongkong	22 18 N	114 10 E	1910	0 00.4 E	30 58.8 N	.37108	.22279
			1911	0 02.4 W	30 58.5 N	.37145	.22297
			1912	0 04.3 W	30 56.3 N	.37193[12]	.22294
			1913	0 06.2 W	30 53.7 N	.37172[12]	.22242
			1914	0 08.5 W	30 53.5 N	.37192[12]	.22251
Honolulu	21 19 N	158 04 W	1909	9 27.3 E	39 51.4 N	.29167	.24350
			1910	9 29.7 E	39 47.2 N	.29161	.24284
			1911	9 32.2 E	39 42.2 N	.29139	.24195
			1912	9 34.8 E	39 38.4 N	.29124	.24128
Cuajimalpa[13]	19 20 N	99 10 W	1911	8 06.2 E	......	......	......
Toungoo	18 56 N	96 27 E	1909	0 30.0 E	23 01.5 N	.38766	.16475
			1910	0 24.9 E	23 02.1 N	.38801	.16498
			1911	0 19.3 E	23 03.0 N	.38853	.16532
			1912	0 13.4 E	23 03.1 N	.38889	.16548
Alibag[14]	18 38 N	72 52 E	1911	0 54.7 E	23 45.9 N	.36856	.16228
			1912	0 51.2 E	23 56.1 N	.36874	.16367
			1913	0 47.6 E	24 04.1 N	.36880	.16472
			1914	0 44.2 E	24 12.6 N	.36882	.16583

[11] Succeeded Zikawei Observatory in 1908. The values are for September to December only.

[12] Based on $P = 7.05$ instead of year's mean as before.

[13] Latitude and longitude approximate.

[14] The values of I and Z (vertical intensity) for 1911, as given in the table, are those determined with dip circle No. 160. Determinations were also made with a Schulze earth inductor, as follows: 1911, $I = 23° 47.'6$N, $Z = .16250$. Beginning with 1912, the values apply to the Schulze earth inductor.

Observatory	Latitude	Longitude	Year	Declination (D)	Inclination (I)	Intensity (C. G. S. units) Hor'l	Vert'l
	° ′	° ′		° ′	° ′		
Vieques...	18 09 N	65 26 W	1909	2 11.7 W	49 44.1 N	.28956	.34185
			1910	2 20.6 W	49 52.0 N	.28863	.34236
			1911	2 29.9 W	50 00.4 N	.28768	.34292
			1912	2 39.0 W	50 09.0 N	.28667	.34346
Antipolo...	14 36 N	121 10 E	1911	0 40.9 E	16 18.2 N	.38205	.11174
Kodaikanal	10 14 N	77 28 E	1909	0 50.1 W	3 39.1 N	.37459	.02391
			1910	0 55.0 W	3 45.2 N	.37485	.02459
			1911	1 00.2 W	3 52.0 N	.37515	.02536
			1912	1 05.8 W	3 59.1 N	.37543	.02616
Batavia-Buitenzorg[15]...	6 11 S	106 49 E	1908	0 50.7 E	31 02.4 S	.36694	.22082
			1909	0 49.5 E	31 09.2 S	.36682	.22175
			1910	0 48.7 E	31 12.0 S	.36660	.22202
			1911	0 47.7 E	31 16.4 S	.36664	.22269
St. Paul de Loanda[16].	8 48 S	13 13 E	1910	16 12.3 W	35 32.2 S	.20125	.14374
Samoa (Apia)...	13 48 S	171 46 W	1908	9 41.9 E	29 21.7 S	.35613	.20036
Tananarive	18 55 S	47 32 E	1907	9 29.7 W	54 05.7 S	.25330	.34986
Mauritius[17]	20 06 S	57 33 E	1910	9 18.1 W	53 34.7 S	.23327	.31615
			1911	9 18.5 W	53 30.6 S	.23310	.31513
			1912	9 25.5 W	53 23.2 S	.23304	.31364
			1913	9 30.0 W	53 17.9 S	.23282	.31234
Rio de Janeiro..	22 55 S	43 11 W	1909	9 28.0 W	....	....	....
			1910	9 40.0 W	....	....	....
Pilar[18].....	31 40 S	63 53 W	1905[19]	9 51.6 E	26 02.9 S	.25912	.12665
			1906	9 45.0 E	26 01.0 S	.25870	.12627
			1907	9 38.1 E	26 00.8 S	.25824	.12602
			1908	9 29.1 E	25 57.2 S	.25810	.12563
			1909	9 21.6 E	25 55.8 S	.25762	.12526
			1910	9 13.9 E	25 52.8 S	.25712	.12474
			1911	9 05.4 E	25 49.4 S	.25699	.12436
			1912	8 57.1 E	25 45.0 S	.25682	.12388
			1913	8 49.0 E	25 43.7 S	.25639	.12355
Santiago...	33 27 S	70 42 W	1909	13 57.9 E	29 57.2 S	....	....
Christchurch..	43 32 S	172 37 E	1910	16 37.6 E	67 54.8 S	.22511	.55474
			1911	16 39.0 E	67 56.2 S	.22494	.55497
Orcadas[20]..	60 45 S	45 01 W	1912	4 46.4 W	54 25.5 S	.25348	.35438

[15] Use is made of magnetograph records from Buitenzorg (6° 35′ S, 106° 47′ E), but the absolute values apply apparently to Batavia. Observatory at Batavia discontinued April 1, 1899, on account of electric-car disturbances.

[16] Means of monthly absolute observations (3 to 4 monthly).

[17] For comparison with previous years, subtract 5.′1 from the declination values beginning with 1912.

[18] See *Terr. Mag.*, vol. 18, p. 195, and vol. 19, p. 112.

[19] Mean of 11 months.

[20] See *Terr. Mag.*, vol. 18, pp. 197-198.

NOTES

10. *Personalia. Karl Haussmann,* the well-known geophysicist and director of the Aachen seismological station, has accepted a call received from the Technische Hochschule in Berlin. *Eduard Brückner* has been elected president of the Vienna Geographical Society. *Prince Boris Galitzin* will give the Halley lecture at the University of Oxford in 1916. *Messrs. J. W. Green, G. Hartnell, H. E. McComb, W. W. Merrymon, F. Neumann, H. W. Pease,* and *E. L. Ulrich*, magnetic observers in the United States Coast and Geodetic Survey, received promotions in salary on August 3, 1915. *Mr. R. L. Faris* has been appointed assistant superintendent, and *Dr. E. Lester Jones*, superintendent of the United States Coast and Geodetic Survey, in succession to *Dr. O. H. Tittmann*, resigned.

11. *Elster and Geitel.* In celebration of the 60th birthday of *Julius Elster* on December 24, 1914, and of *Hans Geitel* on July 16, 1915, a memorial volume was presented to them by their many friends. It is unfortunate, in view of the great contributions to science (about 120 papers) by "Elster and Geitel," that the present conditions have prevented many investigators living outside of Germany from participating in paying tribute to these two distinguished investigators. The doctorate *honoris causa* was conferred upon them by the University of Göttingen and the Braunschweig polytechnicum in recognition of their original contributions to the subject of atmospheric electricity, radioactivity, and photoelectricity. The "Festschrift" contains about 60 articles, and is published by F. Vieweg and Sohn of Braunschweig.

12. *St. Louis Observatory, Jersey, England.* According to a circular received, the St. Louis Observatory of Jersey, after 21 years of existence, is compelled to discontinue its activities because of the present and future difficulties entailed by the present state of war. We must express our regrets to its well-known director and founder, *Marc Dechevrens, S. J.*

LETTERS TO EDITOR

THE MAGNETIC CHARACTER OF THE YEAR 1914.

The annual review of the "Caractère magnétique de chaque jour" for 1914 has been drawn up in the same manner as for the preceding years. Forty-three observatories contributed to the quarterly reviews; 38 of them sent complete data. Table II of the annual review, containing the mean character of each day and each month, the list of "calm days" and the days recommended for reproduction are reprinted here.

G. van Dijk.

Table Showing the Magnetic Character of the Year 1914.

DATES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	MEAN
January	0.2	0.6	0.4	0.7	1.2	0.6	0.9	0.8	0.1	0.0	0.4	0.8	0.9	0.6	0.8	0.9	0.6	0.2	0.1	0.1	0.6	1.3	0.4	0.0	0.0	0.0	0.1	0.7	0.0	0.1	0.2	0.46
February	0.1	0.5	1.0	0.9	0.8	1.0	0.6	0.2	0.2	0.1	0.1	0.2	0.6	0.5	0.9	0.4	0.8	0.9	0.2	0.2	0.1	1.1	0.7	0.5	0.1	0.1	0.1	1.0				0.50
March	0.9	1.1	0.8	0.9	0.4	1.3	1.0	0.3	0.3	0.6	0.9	0.9	0.2	0.5	1.2	0.7	1.0	0.8	0.5	0.6	0.2	0.1	0.4	0.8	0.9	0.6	0.7	0.1	0.1	0.2	0.3	0.62
April	1.0	0.7	0.5	0.2	0.2	1.9	1.4	1.2	0.6	0.7	0.4	0.1	0.2	0.1	0.1	1.0	0.4	0.3	0.8	0.1	0.1	0.1	0.6	0.7	0.1	0.0	0.9	0.4	0.0	0.0		0.50
May	0.1	0.1	0.0	0.0	0.5	0.9	0.5	0.3	0.0	0.1	0.9	0.2	0.1	0.0	0.9	0.8	1.2	0.3	0.0	0.0	0.1	0.1	0.0	0.2	0.8	1.1	0.4	0.5	0.0	0.1	1.2	0.37
June	1.5	0.8	0.8	0.3	0.3	0.4	0.7	0.9	0.1	0.2	0.3	0.0	0.1	0.1	0.6	0.1	0.0	0.2	1.0	0.8	0.3	0.1	0.0	0.1	1.1	1.1	1.2	1.1	0.8	0.7		0.52
July	0.0	0.0	0.0	0.1	1.7	0.8	0.5	0.1	0.5	0.8	0.1	0.1	0.1	0.2	0.4	0.4	0.3	0.6	0.1	0.4	0.6	0.8	0.8	0.9	1.3	0.9	0.7	0.9	1.8	1.4	1.3	0.61
August	0.9	1.0	1.3	0.9	0.5	1.0	0.5	0.4	0.1	0.1	0.8	0.3	0.4	0.1	0.2	0.1	0.4	0.6	0.9	0.9	0.3	0.1	1.2	0.5	0.8	0.6	0.3	1.0	1.4	1.1	0.6	0.61
September	0.1	0.0	0.5	0.8	0.8	0.8	0.0	0.2	0.8	0.7	0.5	0.5	0.1	0.2	0.2	0.8	0.3	0.8	0.2	0.2	0.0	0.2	1.2	0.9	0.4	0.2	1.8	1.0	0.9	0.9		0.53
October	1.1	0.9	0.9	0.5	0.5	0.8	0.9	0.6	0.9	0.7	0.4	0.2	0.3	0.1	0.4	0.6	1.0	0.6	0.6	0.3	0.9	0.7	0.2	0.1	0.0	0.0	1.0	1.8	1.8	0.9	0.2	0.64
November	1.2	0.5	1.2	1.3	0.9	0.2	0.7	0.1	0.0	0.5	1.4	0.9	0.3	1.0	0.8	0.8	0.8	0.5	0.5	0.0	0.0	0.1	0.0	0.1	0.1	1.1	1.1	0.5	0.7	0.4		0.60
December	0.1	0.0	0.5	0.4	0.6	0.1	0.9	0.8	1.0	0.6	0.1	0.3	0.0	0.1	0.0	1.0	0.8	0.1	0.7	0.1	0.0	0.8	0.1	0.9	0.2	0.0	0.9	1.5	0.3	0.8	0.6	0.46

CALM DAYS.

January	9,	10,	24,	25,	26	February	1,	10,	11,	21,	25	March	5,	22,	28,	29,	30
April	12,	15,	26,	29,	30	May	9,	10,	14,	19,	20	June	12,	13,	16,	17,	23
July	2,	8,	13,	17,	19	August	9,	10,	14,	16,	22	September	2,	7,	14,	21,	26
October	12,	14,	24,	25,	26	November	9,	20,	21,	22,	23	December	2,	13,	15,	21,	26

DAYS RECOMMENDED FOR REPRODUCTION.

** April 6, July 5, September 27, October 28.

* February 22, March 6, June 1, June 25, July 29, August 23, November 11, November 26, December 28.

RECORD OF LIGHTNING STROKE AT THE MAGNETIC OBSERVATORY, LUKIAPANG, CHINA, APRIL 13, 1915.[1]

On the morning of April 13, 1915, at $3^h\ 34^m$, China coast time, lightning struck a tree 50 paces southwest of the magnetic hut. At so short a distance, the three self-recording instruments were affected by the shock. In the case of the declinometer and the bifilar, there was an interruption of the tracing, then several minutes of oscillation—about 11′ and 9.8γ, respectively, or a little more, if it is assumed that the first oscillation made no impression on the sensitive paper. The Earth's magnetic field was therefore only slightly modified in direction and in horizontal intensity.

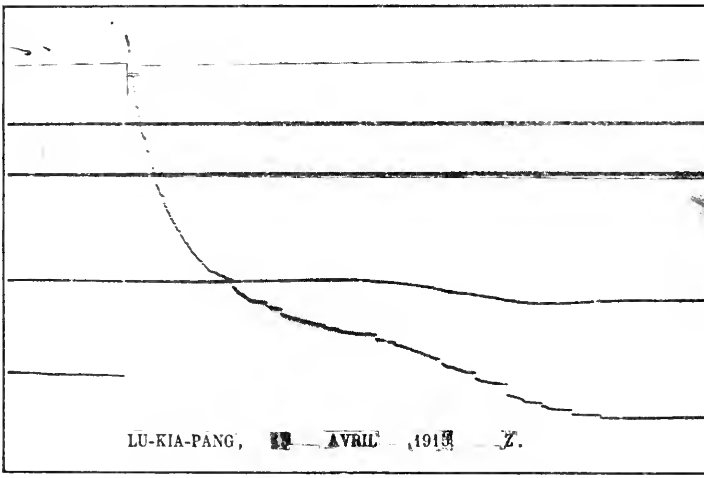

FIG. 1. Vertical-intensity trace, April 13, 1915. (Reduced one-half.)

This, however, was not the case with respect to the vertical intensity (Z). The scale value of the balance had been determined the day before and 4.06γ had been found for the value of a millimeter. On the 15th, after the storm, the scale value was again determined, and 4.75γ was obtained. As our instrument is of rather unstable sensitiveness, there is no proof that this change would not have been produced without the lightning. From the magnetogram (see Fig. 1) it is noted that at $3^h\ 36^m$ there was a violent leap of $+365.4\gamma$ (assuming the scale value of the 12th). This movement is not followed by undulations; the magnet returns, at first quickly, then by little jerks, to its ordinary position. At $11^h\ 35^m$, just eight hours later, equilibrium is again established at 48γ or 49γ lower than at the instant of the violent leap, the position of the trace being now almost what would have been produced at that time by

[1] *Cf.* "Record of Lightning Stroke at Cheltenham Magnetic Observatory," July 12, 1910, *Terr. Mag.*, vol. 15, pp. 211-214. ED.

the diurnal movement, as judged from the trace of the day before on the same sheet. The little jerks are doubtless due to a lack of sensitiveness in our balance which does not respond quickly enough to the smallest indications; it is a defect, without special interest here.

The fact remains that, apparently, the vertical intensity fell progressively during 8 hours. That the local terrestrial-magnetic field required so long a time to recover from the excess of vertical intensity communicated by the lightning stroke, is hard to believe. One would rather think that the effect resulted from the induction in the steel bar itself, which only gradually disappeared.

A like phenomenon has never before occurred at Zi-ka-wei, as far as we know. The fact that the balance suffered no permanent dislocation, was well graduated and measured, perhaps adds some interest to the described event.

Lukiapang, April 25, 1915. J. DE MOIDREY, S. J.

ABSTRACTS AND REVIEWS

S. CHAPMAN: *The Lunar-Diurnal Variation of the Earth's Magnetism.*[1]

Some years ago Schuster developed the mathematical analysis appropriate for a discussion of Balfour Stewart's idea that the diurnal variations of the Earth's magnetism are due to electric currents in the upper atmosphere which owe their origin to the electromotive forces produced by the motion of the conducting atmosphere across the Earth's permanent magnetic field. He adopted the hypothesis that the motion which produces the effect is of a tidal nature and is connected with the diurnal variations of atmospheric pressure. Schuster's calculations were adapted for a discussion of the effect of the barometric waves of solar origin, but he remarked on the desirability of an extension of the work which would deal with the influence on the Earth's magnetism of the tide produced in the atmosphere by the action of the Moon, the possibility of such an effect having been suggested by Balfour Stewart.

The appropriate investigation of the latter effect was commenced by S. Chapman when he was at Greenwich Observatory and has been continued with a thoroughness that commands admiration. In his first memoir Chapman extends Schuster's mathematical analysis so that a more general empirical law may be adopted for the conductivity, ρ, produced in the upper atmosphere by the ultra-violet light from the Sun. Assuming that the value of ρ within a thin spherical shell depends only on the Sun's zenith distance ω, Chapman adopts an empirical law of type $\rho=\rho_0\ (1+\beta \cos \omega)^2$, and chooses β so that ρ is very small on the dark side of the shell in comparison with its value on the illuminated portion. The

[1] On the Diurnal Variations of the Earth's Magnetism Produced by the Moon and the Sun. London, *Phil. Trans.* A., vol. 213 (1913), pp. 279-321; On the Lunar Diurnal Variation of the Earth's Magnetism at Pavlovsk and Pola (1897-1903). *Ibid*, vol. 214 (1914), pp. 295-317; The Lunar Diurnal Variation and its Change with Lunar Distance, *Ibid*, vol. 215 (1915), pp. 161-176.

law adopted by Schuster was of type $\rho=\rho_0\ (1+\gamma \cos \omega)$; but Chapman concludes from his investigation that, in the case of the lunar-diurnal variations, it is necessary to continue the expansion of ρ in powers of $\cos \omega$ at least as far as the term of the second degree in order to obtain an expression of the right magnitude for the amplitude of the fourth harmonic component in the Fourier series representing the disturbing magnetic potential. The special expression for ρ was adopted so that ρ could not be negative, and β was taken to be 3/2.

To test the mathematical theory, Chapman has made a harmonic analysis of the lunar-diurnal variations of declination, horizontal intensity and vertical intensity at Trevandrum, Bombay and Batavia for 8 phases of the Moon. Assuming that the tidal motion possesses a velocity potential of type.

$$P_2^2 (\cos \theta) \sin (2\lambda + 2t' - a).$$

where θ is the colatitude, λ the longitude, t' the local *lunar* time of the standard meridian and a a constant, Chapman obtains a fair agreement with the observational data.

In his second memoir, Chapman makes a harmonic analysis of some observations taken at Pavlovsk and Pola, this being part of a larger undertaking in which he hopes to obtain the data necessary for a discussion of the lunar-diurnal magnetic variations over the whole Earth. As the labor of computation is very large, workers at other observatories are invited to cooperate in the work and so a careful description is given of the method which has been adopted in reducing the observations.

Broun's discovery that the amplitude of the lunar-magnetic variation is greater at perigee than at apogee is discussed in Chapman's third memoir in the light of some new results computed from the hourly values of the magnetic elements at Pavlovsk, Pola, Zikawei, Manila, and Batavia. For periods of four days centered at perigee and apogee the theoretical ratio of the amplitudes is 1.38 while the means of the observed values are 1.33, 1.43 and 1.31, for the declination, horizontal intensity and vertical intensity, respectively. For periods of half a lunation the theoretical ratio is 1.23 while the means of the observed values are 1.23, 0.98 and 1.21 respectively. These results seem to confirm the tidal theory and so Figee's objection to it may probably be laid aside.

Chapman's investigation has also established the reality of a phenomenon noticed by Figee but considered as doubtful. The phase of the lunar-magnetic variation at perigee is considerably in advance of that at apogee (by about 30 degrees). The possibility of explaining this difference in phase on the basis of Darwin's theory of the tides is discussed with the conclusion that the whole of the phase difference cannot be satisfactorily accounted for in this way. Other possible explanations are considered but the author acknowledges that the matter is a mystery.

H. BATEMAN.

NIPPOLDT, A.: *Terrestrial Electricity.*

Chapter No. 16 on "Erdelektrizität" of Müller-Pouillets Lehrbuch der Physik (4ter Band, 5tes Buch, 1914) forms a welcome addition to the literature on the subject, and the inclusion of this field as a part of the general treatment of the subject of magnetism and electricity should serve the purpose of introducing it to a wider circle of physicists.

After a preliminary historical survey, the chapter deals with the atmospheric potential-gradient. The questions of atmospheric conductivity and ionic content are next discussed, and there follows a consideration of the various sources of ionization (radio-active material in the Earth and atmosphere, pentrating radiation, etc.).

In the last third of the chapter an account is given of the various causes influencing the atmospheric-electric elements. An interesting discussion of the electricity of rain and snow is included, and the theories of thunder storms are briefly touched on. A couple of pages are devoted to the theories of the maintenance of the electric field of the atmosphere, and the chapter concludes with an account of Earth-currents, and of the connection between terrestrial magnetism and terrestrial electricity.

On page 1420, a slight error, or departure from custom, is noted. The conductivities λ_+ and λ_- are given as $\epsilon n_- v_-$ and $\epsilon n_+ v_+$, respectively, where ϵ, n and v refer, respectively, to ionic charge, ionic density and specific velocity. This would make λ_+ correspond to the conductivity arising from the negative ions. The point might readily pass as a misprint in the mind of the reader were it not that the paragraph immediately preceding the one in question deals with the dispersion coefficient, and here the designation a_+ for the dispersion coefficient of a positively-charged body, that is, one which loses its charge by negative ions, is in acordance with custom. W. F. G. S.

MELDAU AND MORITZ: *Treatise on the Compass.*[1]

This publication is, as its name suggests, a practical handbook for the navigator. It gives a short account of the principal facts in the subjects of magnetism, terrestrial magnetism, and the magnetism of iron ships. The declination deviation-formula is deduced from a study of cause that separately produce only semicircular and quandrantal deviations. This method is adopted in preference to the purely mathematical treatment as being more suitable to the practical seaman. A new feature in the book is a chapter devoted entirely to a consideration of the Gaussin effect wherein some simple practical applications of Koldewey's lag coefficients are given.

In addition to the W. Thomson vertical-force instrument, there is also a description of the Clausen deflector for measuring approximately the horizontal intensity.

The book will undoubtedly find a ready welcome among Dutch-speaking navigators. W. J. P.

[1] MELDAU, H., and MORITZ, A. J. L. Het Kompas aan Boord van ijzeren en stalen Schepen. Rotterdam, 1915, pp. 120. 24 cm.

LIST OF RECENT PUBLICATIONS

A. Terrestrial and Cosmical Magnetism.

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BEATTIE, J. C. Further magnetic observations in South Africa. Repr. Cape Town, Trans. R. Soc. S. Afric., v. 4, Pt. 1, 1914 (9-56).

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BUSS, A. A. The magnetic storm and solar disturbance of June 17 [1915]. Nature, London, v. 95, No. 2387, July 29, 1915 (589-590).

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DE BILT. METEOROLOGICAL AND MAGNETIC OBSERVATORY. Annuaire. Soixante-cinquième année. 1913. B. Magnétisme terrestre. (K. Nederlandsch Meteor. Inst. No. 98.) Utrecht, Kemink & Zoon, 1914 (46). 32½ cm.

DYSON, F. W. Report of the Astronomer Royal to the Board of Visitors of the Royal Observatory, Greenwich. Read at the Annual Visitation of the Royal Observatory, 1915, June 5. Greenwich, Royal Observatory, May 26, 1915, 21 pp. 31 cm. [Contains on pp. 15-16, account of the magnetic observations and the mean values of the magnetic elements for the years 1911, 1912, 1913, and 1914, at the Royal Observatory, Greenwich.]

FARIS, R. L. Terrestrial Magnetism. Art. in American Year Book, 1914. New York, D Appleton & Co., 1915 (600-601).

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME XX DECEMBER, 1915 NUMBER 4

SOLAR RADIATION AND TERRESTRIAL MAGNETISM.[1]

BY L. A. BAUER.

1. One of the foremost magneticians of the last century, after a lifelong and devoted study of the various phenomena of the "Earth magnetical," said in a public address: "Viewed in itself and its various relations, the magnetism of the Earth cannot be counted less than one of the most important branches of the physical history of the planet we inhabit." I shall endeavor to show briefly, in the paper which I have the honor to present before you, the rôle certain terrestrial-magnetic phenomena may play in the study of the physical characteristics of our atmosphere, especially of those upper levels, 100 kilometers and more above us, to which man has not yet succeeded in sending his exploratory instruments.

2. Among the most striking of the Earth's magnetic phenomena is the diurnal variation which takes place chiefly during the daylight hours, and varies in its magnitude and general characteristics with geographic position with the season of the year, and with Sun-spot activity. A preliminary mathematical analysis, made by Schuster and presented before the Royal Society of England in 1889,[2] led to the conclusion that "the principal part of the diurnal variation is due to causes outside of the Earth's surface, and probably to electric currents in our atmosphere."[3] Furthermore, Schuster found "that the horizontal movements in the atmosphere which must accompany a tidal action of the Sun or Moon or any periodic variation of the barometer, such as is actually observed, would

[1] Summary of two papers bearing the following titles: "Solar Radiation and Terrestrial Magnetism," presented before the joint meeting on Atmospheric Physics, of Section *B* (Physics) of the American Association for the advancement of Science and the American Physical Society, San Francisco, August 5, 1915; "Concomitant Changes in Terrestrial Magnetism and Solar Radiation," read at the New York meeting of the National Academy of Sciences, November 17, 1915.

[2] *Phil. Trans. R. S.*, vol. 180, A, pp. 467-518, 1889.

[3] This conclusion was in the main verified by the later and more comprehensive investigation of Fritsche, who, however, found that the portion of the diurnal variation to be ascribed to causes *below* the Earth's surface was larger than indicated by Schuster's results.

produce electric currents in the atmosphere having magnetic effects similar in character to the observed diurnal variation." In brief, the hypothesis adopted by Schuster to account for the supposed electric currents, generated in the upper atmoshperic regions, was the one first proposed by Balfour Stewart—that the necessary electromotive forces for the production and maintenance of the required electric currents are generated by the motion of masses of conducting air across the lines of the Earth's permanent magnetic field, chiefly of the vertical component, thus bringing into play Foucault currents.

3. Schuster found further that the mathematical analysis was simple so long as the electric conductivity of the air was taken to be uniform and constant; but the great ionization demanded by the theory required some explanation, and solar radiation suggested itself as a possible cause. "Hence," he says, "we might expect an increased conducting power in summer and in daytime as compared with that found during winter and at night." We have now reached the immediate subject of inquiry of our paper. If solar radiation plays the prominent part required in the Schuster analysis[1] of the diurnal variation of the Earth's magnetism, the question naturally arises: *If, at any particular moment or period, the intensity of the solar radiation falling upon the Earth's atmosphere suffers, from some cause, an appreciable increase or decrease is there a corresponding observable magnetic change?*

4. A diminution, for example, in the intensity of solar radiation, could be caused by the interposition of some screening body between the Sun and the Earth. The interposing body might be the Moon, as during a total solar eclipse, or a cooling layer above the Sun's photosphere. In the first case magnetic observations made during a total solar eclipse would shed some light, and in the second case, a comparison of observed values of the solar constant with concomitant magnetic records would be of great interest. We have carried out both lines of inquiry.

MAGNETIC CHANGES DURING TOTAL SOLAR ECLIPSES.

5. Beginning with the total solar eclipse of 1900, the totality belt of which crossed the southeastern part of the United States,

[1] See also the recent papers by S. CHAPMAN: On the diurnal variations of the Earth's magnetism produced by the Moon and Sun, *Phil. Trans. R. S.*, vol. 213, A. pp. 279-321, 1913; On the lunar diurnal variation of the Earth's magnetism at Pavlovsk and Pola (1897-1903), *Phil. Trans. R. S.*, vol. 214, A. pp. 295-317, 1914; The lunar diurnal magnetic variation, and its change with lunar distance, *Phil. Trans. R. S.*, vol. 215, A. pp. 161-176, 1915.

every opportunity has been taken to inaugurate and to stimulate the making of magnetic observations during total solar eclipses. In consequence, a mass of magnetic data has now been obtained which will serve for a comprehensive study in the near future of the important question as to whether an appreciable magnetic change is experienced at stations lying in or near the belt of totality of a solar eclipse. The difficulty of this investigation is increased by the fact that the expected magnetic change is necessarily a small quantity which must be differentiated from the larger changes occurring more or less regularly during the day, and from the still more troublesome, spasmodic changes due to magnetic perturbations, or to magnetic storms affecting the whole Earth at about the same time. Accordingly the fundamental principle of investigation laid down by the author, the importance of which has sometimes been overlooked by others, was to secure magnetic observations at stations strung out along the path of totality, and at as many stations as possible outside this path of totality, and in all parts of the Earth. By this means it is feasible to separate a possible eclipse magnetic variation from the regular diurnal variation, and any world-embracing magnetic perturbations, since the first variation might be expected to run through its phases not according to local time, nor to absolute time, but according to the time of passage, approximately, of the shadow cone from station to station.[5]

6. As the chief result[6] of my preliminary investigation of the magnetic observations obtained during the eclipses of 1900 and 1901, the conclusion was drawn "that an observable magnetic variation makes itself felt during the time of a total solar eclipse, and that this variation is analogous in its nature to the solar-diurnal magnetic variation, differing from it only in degree." The range of the eclipse magnetic variation, as observed, for example, at my station at Rocky Mount, North Carolina, on May 28, 1900, was for the magnetic declination 0′.9 against 10′.8 for the regular solar-diurnal magnetic variation. The eclipse magnetic effect may also be tersely characterized thus: the general effect was that of an interruption or retrogression of the normal magnetic diurnal variation such as would happen by the interposition during the daylight hours of the nighthour effect. Thus, for example, at Rocky Mount during the eclipse of May 28, 1900, west magnetic

[5] See Pl. VII, vol. 5, p. 154, *Terr. Mag.*, illustrating this phenomenon for the eclipse of 1900.

[6] *Terr. Mag.*, vol. 7, p. 192, 1902.

declination began to increase just before totality (about 8:40 A. M.), whereas normally it should have been decreasing, and after totality it began to resume its usual course.[7] This retrogressive effect in the usual march of the magnetic diurnal variation is well illustrated by the vector diagram, combining the observed changes both in the magnetic declination and in the horizontal intensity.[8]

Another extremely interesting conclusion reached from an analysis showed that the chief cause producing the eclipse effect was situated above the Earth's surface, just as Schuster had shown it to be for the magnetic diurnal variation. It was furthermore found that the cause moved along the belt of totality, lagging somewhat behind the Moon's shadow.[9] Effects similar to those found during the eclipse of 1900 are revealed by a preliminary examination of the magnetic data, at present available, obtained during the total solar eclipse of August 21, 1914.

7. The apparent effect at Rocky Mount, during totality, on the local magnetic constant (G)[10]—a quantity proportional, under certain assumptions, to the Earth's intensity of magnetization—was that of a momentary increase, the maximum effect occurring some minutes after totality. The total range of the eclipse effect amounted to about one-fiftieth per cent of G.

Changes in Solar Radiation and the Earth's Magnetism.

8. We next come to a comparison of changes in the intensity of solar radiation, as revealed by Abbot's solar-constant values, with concomitant magnetic changes. The difficulties referred to in paragraph 5 with regard to determining the eclipse magnetic effect, namely, the elimination of all magnetic effects attributable to causes other than the one under immediate investigation, enter also here in even a more pronounced degree. From *a priori* considerations it appears at once that a magnetic effect associated with the maximum change in the solar constant observed during any year by Abbot—about 10 per cent—is perhaps a quantity of the order of magnitude about 4 or 5 times the general limit of accuracy of recording magnetic instruments. But a 10 per cent change in the solar constant is usually distributed over several months during which the Earth's magnetic elements have suffered changes,

[7] *Terr. Mag.*, vol. 5, pp. 151-154, 1900.

[8] *Idem.*, vol. 5, fig. 1, p. 157, 1900.

[9] *Idem*, vol. 5, pp. 162 and 165, 1900.

[10] *Idem*, vol. 19, pp. 113-115, 1914.

because of seasonal change, or of secular variation, by quantities larger than those attributable, perhaps, to changes in solar radiation. In order to eliminate, as effectively as possible, the undesired magnetic variations, the magnetic data and solar data for a period not extending much over 10 days must be utilized. Furthermore, during such a 10-day period, it is necessary to group the solar and the magnetic data so that the mean date for, let us say, 5 low values of solar constant corresponds, as nearly as possible, to the mean date of 5 high values. As solar-constant observations, for various reasons, cannot be observed every day, it must happen at times that for any one group there are available only 3 or 4 low values and about the same number of high values. Hence, generally, for a group the difference between mean low and mean high solar-constant is not more than about two per cent. The errors in individual values of the solar constant may amount to one or two per cent, or the error of the mean difference in the solar constant for one of our groups may be about one-half to one per cent. Suffice it to say that to reach any definite result, concomitant solar and magnetic data covering a number of months during a period of comparatively few magnetic disturbances are necessary, i. e., during years of minimum Sun-spot activity as, for example, 1911, 1912, and 1913.

9. At the meeting of the American Astronomical Society in 1914, results[11] of a preliminary investigation were announced which were based on solar and magnetic data for 1911 and 1912. As a provisional result it was stated that for a maximum change of 10 per cent in the solar constant there was found, apparently, a change in the local magnetic constant of about 1/30 per cent of its value (or a 1 per cent change in solar constant corresponded to about 0.003 of G), decreased solar constant corresponding to increased magnetic constant. Dr. Abbot has kindly furnished me, in advance of publication, with his solar-constant values for 1913. These values cover the period July 16 to November 9, 1913. However, because of change of instrument on September 22, we are, at present, limited to the period July 16-September 21. The maximum value for this period of 1.994 occurred on September 18, and the minimum, 1.859, on August 19, the difference amounting thus to 0.135, or 7 per cent. As magnetic data there were available the published observations at the European magnetic observatories Potsdam (Seddin), Pola, and Del Ebro, and the corresponding

[11] *Terr. Mag.*, vol. 19, pp. 119-124.

data for the five magnetic observatories, Porto Rico, Cheltenham (Maryland), Tucson (Arizona), Sitka (Alaska), and Honolulu (Hawaii), which were supplied in manuscript by courtesy of the Superintendent of the Coast and Geodetic Survey.

10. Excluding days of cosmic magnetic disturbances, it was possible to combine the available solar and magnetic data for 1913 into 4 groups, each group containing from 4 to 10 values of the solar constant and the same number of values of the magnetic element under consideration. Table 1 gives the mean results for

TABLE 1. *Changes in the Local Magnetic Constant (G) During 1913 for a Decrease of One Per Cent in the Solar Constant.*

Station	Lat.	Long.	Dip	G	From Same Time		From Daily Means				Weight
					dG	x=dG/G	dH	dZ	dG	x=dG/G	
	°	°	°	c.g.s.	γ	.001%	γ	γ	γ	.001%	
Pola	44.9 N	13.8 E	+60	.294	+0.35	+1.2	+0.64	+1.04	+0.83	+2.8	2
Seddin	52.4 N	13.1 E	+66	.285	+0.69	+2.4	+0.67	+0.56	+0.65	+2.3	3
Del Ebro	40.8 N	0.5 E	+58	.297	+1.04	+3.5	+0.86	+0.003	+0.68	+2.3	1
Porto Rico	18.2 N	65.4W	+50	.333	+1.03	+3.1	+0.70	+0.19	+0.66	+2.0	2
Cheltenham	38.7 N	76.8W	+71	.341	+0.15	+0.4	+0.50	−0.82	−0.05	−0.1	2
Tucson	32.2 N	110.8W	+59	.356	+0.63	+1.8	+0.72	−0.40	+0.39	+1.1	2
Sitka	57.1 N	135.3W	+74	.321	+0.37	+1.1	+0.42	−0.38	+0.03	+0.1	1
Honolulu	21.3 N	158.1W	+40	.314	+0.51	+1.6	+0.44	−0.54	+0.30	+1.0	2
	Weighted Mean					+1.87	Weighted Mean			+1.53	
	Resulting value of x = dG/G, from both computations, is +0.0017 per cent.										

each of the 8 observatories and shows the proportional increase ($\triangle G/G = x$) in the local magnetic constant[12] associated with a one per cent *decrease* in the solar constant, by two different methods of computation, assuming for the present a linear relation between solar and magnetic effects. The values of x, expressed in

[12] According to reference in footnote 10, $G = \sqrt{H^2 + \frac{1}{4} Z^2}$ and $dG = \frac{H}{G} \cdot dH + \frac{1}{4} \frac{Z}{G} \cdot dZ$, H being the horizontal, and Z, the vertical intensity.

units of 0.001 per cent of G, given in the seventh column, are derived from the magnetic data for the same absolute time of each day during which the solar observations are made (about 7 to 11 A. M., Mount Wilson time, or about 3 to 7 P. M., Greenwich time). The column before the last one contains the results for x derived by using the daily mean magnetic elements resulting from the continuous observations during 24 hours; Abbot's experience was that a high or low value of the solar constant may often persist for a day and, in fact, several days. The weight 3 was assigned to the results from Seddin because of the smoothing out of mean hourly values resulting from the method employed at that observatory; the weight 2 was given to the other observatories excepting Del Ebro (somewhat incomplete data) and Sitka (more or less disturbed data), to which the weight 1 was assigned.

11. It will be seen that the results from the two methods of computation are practically identical at each station, and that only once out of 16 times has the resultant quantity ($x = \triangle G/G$) a negative sign. Hence we may conclude, apparently, that a 1 per cent decrease in the solar constant during 1913 corresponded, on the average for the observatories considered, to + 0.0017 per cent increase in the local magnetic constant. While the present quantity is apparently but half of that obtained from our provisional investigation of last year (see ¶ 9), note that it is of the same order of magnitude, and of the same sign. The 1911 and 1912 magnetic data at Pola and Seddin were compared with the solar data at Bassour, Algeria; these, according to Abbot, are less perfect than the Mt. Wilson ones.[13] Hence we have now compared all magnetic changes with changes in solar constant as shown by the observations at Mount Wilson. The weighted mean value of x then resulting from the first provisional investigation for Seddin (1911, 1912), Pola (1911, 1912), Tucson (1911, 1912), and Baldwin (1906, 1908) is + 0.0021 per cent of G. Accordingly, the combined provisional result from our two preliminary investigations is as follows: *One per cent decrease in the intensity of solar radiation is accompanied, apparently, by an increase of about 0.002 of a per cent in the magnetic constant used as a measure of the changes shown in the Earth's magnetic state.*

12. To obtain further verification we next examined into the question as to whether days of low solar constant, on the average, show a slightly smaller range of the magnetic diurnal variation

[13] See *Annals of the Astrophysical Observatory of the Smithsonian Institution*, vol. III, 1913.

than do days of high solar constant, just as is found during winter as compared with summer. The solar and magnetic data for 1913 were grouped in the same manner as before. Let $\triangle D$, $\triangle H$, and $\triangle Z$ be the tabulated diurnal ranges of the magnetic elements as given in observatory publications, and let dD, dH, and dZ be the resulting changes in those quantities for a one per cent decrease in the solar constant. Suppose, furthermore, the ratios $dD/\triangle D$, $dH/\triangle H$, $dZ/\triangle Z$ to be represented, respectively by, y_1, y_2, and y_3. In Table 2 will be found the values of these quantities as derived from the available magnetic and solar data of 1913 for the 8 observatories already named. A minus sign means a decreased diurnal range. It will be seen that in 18 out of 22 cases, or 82 per cent, the sign is minus, i. e., decreased magnetic diurnal range corresponds to decreased solar constant. Considering the minuteness of the effect and the difficulties of the investigation, both as regards the solar and the magnetic data, we must be satisfied with this degree of agreement.

TABLE 2. *Proportional Decrease in the Range of the Magnetic Diurnal Variation During 1913 for a Decrease of One Per Cent in the Solar Constant.*

Station	Lat.	Long.	Dip	Decl'n $10y_1$	Hor. Int. $10y_2$	Ver. Int. $10y_3$	Weight
	°	°	°				
Pola	44.9 N	13.8 E	+60	−0.1	+0.4	−0.1	2
Seddin	52.4 N	13.1 E	+66	−0.2	−0.2	−0.2	3
Del Ebro	40.8 N	0.5 E	+58	−0.1	....	....	1
Porto Rico	18.2 N	65.4 W	+50	−0.05	+0.4	−0.4	2
Cheltenham	38.7 N	76.8 W	+71	−0.2	−0.4	+0.6	2
Tucson	32.2 N	110.8 W	+59	−0.2	−0.4	−0.2	2
Sitka	57.1 N	135.3 W	+74	−0.1	−0.4	−0.1	1
Honolulu	21.3 N	158.1 W	+40	0.0	−0.4	+0.2	2
				−0.13	−0.12	−0.02	
Weighted mean, 10y					−0.09		

The average value of $10y$ is about -0.1, or $y = -0.01$. Hence, *a decrease of one per cent in the solar constant would apparently correspond, as far as the present computations show, to a decrease of about one per cent in the diurnal ranges of the magnetic elements.*

The comparison of solar and magnetic data, such as were available for 1914, confirmed, in general, the previous results. The quantities were of the same sign as before, though somewhat diminished in magnitude, for reasons which became apparent after the investigation described in paragraphs 14 to 17 had been completed. In 1914 the individual station-results, even on supposedly quiet days, showed marked local peculiarities. When the 1914 data from observatories extending over the globe have been received, a more complete examination will be made.

13. Comparing the data in paragraphs 6, 7, 11, and 12, we find that the eclipse magnetic effect on the diurnal range of the magnetic declination, as well as on the value of the local magnetic constant, *G*, was of the sign, and of the order of magnitude of the magnetic effects, which are, apparently, to be associated with about a 10 per cent decrease in the value of the solar constant.

Non-Cyclic Magnetic Effects.

14. Owing to the secular change of the Earth's magnetism, the daily mean values of the magnetic elements progress from day to day in some systematic manner. Consequently, even if these daily values are the result of continuous observations throughout 24 hours, eliminating thus, as effectively as possible, the diurnal variation effects, the local magnetic constant will not be the same to-morrow as it was to-day. Or, putting it in another way, even were we able to eliminate all effects due to diurnal variation, seasonal variation, magnetic perturbations, etc., the value of this constant at midnight to-night would be different from that at midnight last night. We have thus a non-cyclic change (*a*) due to the secular variation.

But there is a more serious outstanding daily effect than this, even on days of apparently no magnetic perturbations. As the result of an arbitrary convention, certain days, 5-10 a month, are selected by magneticians as "magnetically quiet days," the so-called "normal days." These days are determined by an examination of the daily magnetograms, and those showing a comparative absence of perturbations are designated as the "quiet" ones. Several investigators have found, however, that these "quiet" days exhibit certain peculiar phenomena; while the curves on these days may be comparatively smooth, the diurnal range may perhaps be larger than on unquiet days, or the daily mean magnetic elements suffer a larger decrease or increase than those of other days. That

is, there may be a change of the quiet kind progressing, more or less steadily, throughout the day so as to cause, on the average for the day, a displacement, up or down, of the magnetic curve with regard to its base line.

Chree, who has paid special attention to the non-cyclic change on quiet days (*b*) found the following interesting results[14] with respect to the horizontal intensity (H) and the vertical intensity (Z):

Mean of Years	dH		Mean of Years	dZ	
	Kew	Falmouth		Kew	Falmouth
	γ	γ		γ	γ
1890–1909	+3.03	+2.78	1890–1900	−0.25	−0.84

These quantities, dH and dZ are derived thus: The midnight values of H and Z at the beginning of a quiet day (0^h) are subtracted from those at the end (24^h) of the same day. The mean yearly result from the 5 quiet days of each month had the same sign (+ for dH and − for dZ) for each year of the entire period, excepting one case (dZ at Falmouth in 1894, which was plus instead of minus; at this station, however, there have been certain instrumental difficulties which would affect the Z results).

15. Steiner recently made a more exhaustive investigation of the non-cyclic change on quiet days.[15] He obtained his quantities, in general, by subtracting the mean daily magnetic elements on one quiet day from those on the following quiet day. For the 10 observatories investigated,[16] which covered practically all parts of the Earth, he found the same remarkable persistence in signs as did Chree. Thus, for each observatory and practically for each year of observation, dH was plus and dZ minus. Weighting the individual results according to the number of years of observations, the mean results from the 10 observatories were: $dH = +1.85\gamma$; $dZ = -0.68\gamma$. I have computed also for each observatory investigated the change in the local magnetic constant and find for the average result on quiet days: $dG = +1.13\gamma$ and $dG/G = +0.0036$ per cent. It is evident that we are dealing here with a

[14] *Studies in Terrestrial Magnetism*, p. 26, 1912.

[15] *Terr. Mag.*, vol. 19, pp. 73-80, 1914.

[16] These were: Pola, 1903-'09; Potsdam, 1903-'07; O'gyalla, 1906-'08; Pavlovsk, 1897-1906; Zi-ka-wei, 1904-'07; Honolulu, 1902-'12; Sitka, 1902-'12; Baldwin, 1901-'09; Cheltenham, 1901-'12; Vieques, Porto Rico, 1903-'12.

world, or universal phenomenon. Hazarding a question, may not this phenomenon be associated in some way with changes in the intensity of solar radiation? We find that the average daily change in the solar constant, 1905-1914, regardless whether it is an increase or a decrease, is 0.030 of a gram calory per square centimeter per minute, or about 1.5 per cent of the mean solar constant (1.934). Consulting paragraph 11, we find that one per cent decrease in the solar constant is accompanied apparently by an increase in the magnetic constant (G) of 0.002 per cent. Hence, assuming proportionality, 1.5 per cent decrease in the solar constant should be accompanied by 0.003 per cent increase in G. From the quiet days we have just found the average daily change in G to be 0.0036 per cent, hence a close coincidence with the result given in the previous sentence.

16. The query at once arises: Is the intensity (S) of solar radiation less on the average on the second quiet day than on the first? If so, dS computed in the same way as were the magnetic quantities for the consecutive quiet days should turn out to be, on the average, minus. That is, we should have a decrease in the solar constant associated again with an increase in the magnetic constant and the quiet-day results, based upon the quantities derived from the investigations by Chree and Steiner, would be in complete harmony with what we have found in an entirely independent manner.

To examine provisionally into these queries, we selected all consecutive quiet days (Case *A*), as indicated by the records of the Cheltenham magnetic observatory, 1905-1914, for which there were corresponding values of the solar constant. Seventy of such pairs of days were found, and the dG was computed for each pair. If x be the change expressed in thousandths of a per cent change in G for one per cent change in S, we have 70 conditional equations of the form $x\ dS = dG$. The resultant normal equation is: $185.3\ x = -107.3\gamma$, hence, $x = -0.579\gamma = -0.0017$ per cent of G—a result in excellent agreement with that in paragraph 11. If dS and dG are of the same sign, then $dS\,dG$ should be plus; if dS and dG are of opposite signs, then $dS\,dG$ should be negative. For the 70 cases, we had $\Sigma dS\,dG = -154.5 + 47.2 = -107.3$. Accordingly, for 76 per cent of the summation dS and dG are of opposite sign, i. e., a decrease in S, for example, corresponds, in general, to an increase in G—hence a result again in complete harmony with that in paragraph 11.

Furthermore, $\Sigma\, dS^2$ for the negative cases of dS is found to be 116.3 against 69.0 for the positive dS's—or about two times the sum for the latter. In other words, *for a pair of consecutive magnetically-quiet days, the intensity of solar radiation (the solar constant), is found, on the average, to be less on the second day than on the first*, i. e., the dS is, on the average, negative. Hence, since decreased solar constant corresponds to increased magnetic constant, it happens that the average dG is positive, as we have just found. Or since the dG depends primarily upon dH, we may also say that *the reason for the persistent positive sign in the annual mean values of dH, as disclosed by the researches of Chree and Steiner for quiet days, is that the value of the solar constant on the second quiet day is, on the average, less than on the first.*

17. Suppose we investigate next Case *B*. What happens if, instead of taking a pair of consecutive quiet days, we take one quiet day and the preceding one which is moderately unquiet? For the series 1905-1914, 57 pairs of such days were found for which there were both solar and magnetic data. Again only the Cheltenham magnetic records were utilized, these data having been promptly supplied by the United States Coast and Geodetic Survey. For the resulting normal equation we now have: $196.8z = -37.1\gamma$, or $z = -0.19\gamma = -0.00056$ per cent of G—only one-third of the value found from the two consecutive quiet days. The sum of $dS\, dG$ for the pairs having like signs of dS and dG is $+50.5$, against -87.6 for the cases of unlike signs. Furthermore, the sum of dS^2 for the negative cases of dS is 116.0, and for the positive ones, 80.8. In other words, while, on the average, the resultant quantities have the same sign as for the series of consecutive quiet days, the magnitudes for Case *B* are considerably reduced. Hence, *for a pair of consecutive days of which the first is moderately unquiet and the second quiet, the solar constant is, on the average, only slightly less on the second day than on the first.*

As a third test (Case *C*), let us take pairs of consecutive days of which the first day is quiet and the second moderately unquiet. For the Cheltenham series 1905-1914, 57 pairs of this kind were found on which both solar and magnetic data were available. We have now $175.4z = -45.0$, hence $x = -0.256\gamma = -0.00075$ per cent of G. Also $\Sigma\, dS^2$ for negative dS's is 121.1, and for the positive ones, 54.3. The quantities have the same signs as for cases (*A*) and (*B*), but, as for (*B*), they are smaller than for (*A*).

The conclusions drawn, from the present preliminary investigation, are:

(*a*) The change in the magnetic constant corresponding to 1 per cent change in the solar constant is, on the average, larger for a pair of consecutive quiet days than for pairs of consecutive days in which one day is quiet and the other moderately quiet. The replacing of a quiet day by a moderately unquiet one has the effect of reducing the change in the magnetic constant for a 1 per cent change in the solar constant.

(*b*) The results from pairs of consecutive quiet days are, apparently, sufficiently pronounced to lead to the belief that, in general, it will be found that the solar constant is less on the second quiet day than on the first.

Secular Change of the Earth's Magnetism.

18. If the non-cyclic effect which we found to result in an increase in the magnetic constant of about 0.0036 per cent on quiet days persisted every day throughout the year, we should get an annual secular change 10 times, or more, than ordinarily found. There must, therefore, be an opposite effect on the unquiet days. This may be surmised from the results found for the two cases (*B*) and (*C*) discussed in the previous paragraphs, as well as from the fact that the net result of a magnetically-disturbed day is to diminish the magnetic constant. The quiet-day effect persists only for one-third of a year or less, and the disturbance-effect hence prevails for the greater part of a year. The so-called quiet days, instead of being normal ones, are, in fact, sub-normal days.

Since we have associated certain magnetic changes with solar changes, and since the latter do not appear to be periodic, but are themselves subject to annual changes, which are more or less spasmodic in character, it would be unreasonable to expect an exact annulment in a year of the two opposite effects (those of the quiet day and those of the unquiet day). In other words, the presumption is that there should be a residual effect at the end of the year resulting from those magnetic changes associated directly with changes in solar radiation. Accordingly, *if we compare annual secular changes with annual solar-constant changes, may we expect to find any correspondence?*

A preliminary examination of this interesting question has been made, the results of which are stated in conclusion *F*, page 157. A future paper will be devoted to a fuller discussion of the relation between changes in solar radiation and in the secular variation of the Earth's magnetism. There also the relation between solar radiation and the magnetic annual variation will be discussed.

Analysis of the Solar Radiation Magnetic Effect.

19. A preliminary investigation has been made of the question as to the seat of the system of the forces to which the magnetic changes, apparently associated with solar-radiation changes, might be referred. It appears that, as in the case of the magnetic diurnal variation, the seat of the system is chiefly above the Earth's surface. A more complete examination of this question than is now possible, as well as a discussion of the *modus operandi* by which the observed effects are brought about, must be reserved for a later paper.

In conclusion acknowledgement should be made of the aid rendered in the computations by Messrs. Duvall, Fisk, Wallis, and Mills, all of the Department of Terrestrial Magnetism. Furthermore, the invaluable assistance rendered by the Astrophysical Observatory of the Smithsonian Institution and the United States Coast and Geodetic Survey by the prompt transmission of their respective data, deserve special mention.

Chief Conclusions.

A. Changes in the Earth's magnetism of appreciable amount are found associated with the changes in solar radiation as shown by values of the solar constant possessing the requisite accuracy. For the average daily change in the solar constant, which amounts to about 1.5 per cent, the magnetic constant, used as a measure of the prevailing magnetic state of the Earth, suffers a change of about 0.003 per cent, or about one digit (1γ) in the fifth decimal C.G.S. units. The effect on the horizontal component of the total intensity of the Earth's magnetic force would be about twice this, or about 2γ.

B. Decreased solar constant appears to be accompanied by increased magnetic constant and decreased diurnal range of the Earth's magnetism, in accordance with the following relations: One per cent change in the solar constant is accompanied by a change of about 0.002 per cent, about (0.6γ) in the magnetic constant, and by about one per cent in the magnetic diurnal range. Assuming, for the present, a linear relation between solar and magnetic changes, we may expect, for a 10 per cent change in the solar constant, as occasionally occurs, a change in the magnetic constant of about 0.02 per cent, and of about 10 per cent in the magnetic diurnal range.

C. The magnetic effects observed during total solar eclipses are

in general harmony with (*A*) and (*B*) and are equivalent to those which might be expected from about a 10 per cent change in the intensity of solar radiation.

D. Since the changes in solar radiation are aperiodic and occur more or less spontaneously, the effect on the Earth's magnetism is generally of a threefold character: (*a*) An alteration in the diurnal range, (*b*) perturbations both of the world-wide and the local kinds, (*c*) an outstanding residual effect such as to alter the daily mean values of the magnetic elements by an amount 10 to 100 times that caused by the regularly-progressing secular variation. The magnitude of the effects may at times exceed the average ones described in (*A*) and (*B*), dependent upon peculiar local conditions (ionizations) of the upper atmospheric layers. Changes in solar radiation may thus furnish sufficient cause for the ever-present minor perturbations and elementary waves, or pulsations, of the Earth's magnetism, as also for the peculiar, special, or local type of perturbations.

E. The daily non-cyclic changes in the Earth's magnetism, as found on magnetically-quiet days by previous investigators, furnish an additional check on the foregoing results, their quantities harmonizing completely, both as regards sign and magnitude, with those given here. It is found that on consecutive quiet days the magnetic constant is, on the average, larger on the second day than on the first, the increase being equal to that which would be caused by an average daily change in the solar constant (Cf. *A*). Moreover, the reason why the magnetic constant, or the horizontal intensity, is larger, on the average, on the second quiet day is because, on the average, the solar constant is slightly *smaller* on the second day than on the first. The relation between solar change and magnetic change during consecutive quiet days is precisely of the same sign and amount as given in (*B*).

F. If the quiet-day magnetic effect were to persist throughout the year, it would cause a secular variation fully 10 times that generally observed. However, the quiet days are in the minority, being exceeded 3 times and more by unquiet days, on which the magnetic effect is of an opposite or compensating kind to that of the quiet day. Since these acyclic effects appear to be associated with solar changes and since the latter are not periodic, but more or less sporadic, there is an outstanding effect at the end of the year which causes an irregularity in the regularly-progressing secular change. Accordingly, there should be found some cor-

respondence between annual changes of the solar constant and annual magnetic changes. This is found to be the case. Since the solar-constant changes occur only approximately in accordance with sun-spot activity, and since the magnetic changes are found to conform closely to those in the solar constant, an explanation is found as to why the irregularities in the magnetic secular change do not always synchronize with changes in solar activity as measured by the sun-spot numbers, nor correspond in magnitude to them.

G. Just how far changes in solar constant, derived from that portion of the solar radiation which affects the pyrheliometer, may be taken as a true measure of those changes in the Sun's activity which really are the cause, directly or indirectly, of the magnetic changes, requires further investigation. The magnetic effects may be found to be more truly related to changes in the ultra-violet part of the solar radiation and to the entrance into our atmosphere of charged particles. To the ultra-violet light and to these charged particles we must chiefly assign changes in ionization and conductivity of the upper atmosphere. Unfortunately, the fluctuations of the ultraviolet part have not, as yet, been separately determined by solar-constant observations. The relation between changes in solar constant and magnetic constant is of such a definite character as to make it appear that one set of changes may furnish an effective control over the other.

DEPARTMENT OF TERRESTRIAL MAGNETISM,
CARNEGIE INSTITUTION OF WASHINGTON.

PRELIMINARY REPORT ON THE RESULTS OF THE AURORA-BOREALIS EXPEDITION TO BOSSEKOP IN THE SPRING OF 1913. (THIRD COMMUNICATION.)

By Carl Störmer, *Kristiania.*

1. In this Journal for September, 1913, and March, 1915, preliminary accounts were published by me of some results of the aurora-borealis expedition to Bossekop, which I undertook in the spring of 1913. The present communication concerns the very extensive material of the nights, March 14, 15, and 15, 16, 1913, comprising about 100 auroral photograms.

The main conclusions of the second report are confirmed, especially in regard to the lower limit of the altitude of the aurora, as will be seen in Fig. 1, representing graphically the height above the Earth's surface of all the points of the aurora, which have been calculated.

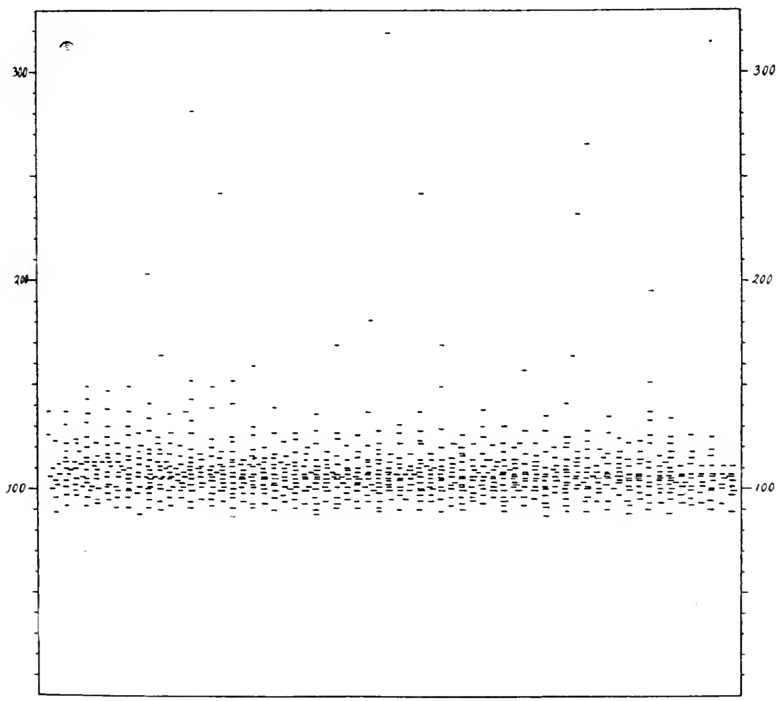


Fig. 1. Altitude of Aurora, March 14-16, 1913.

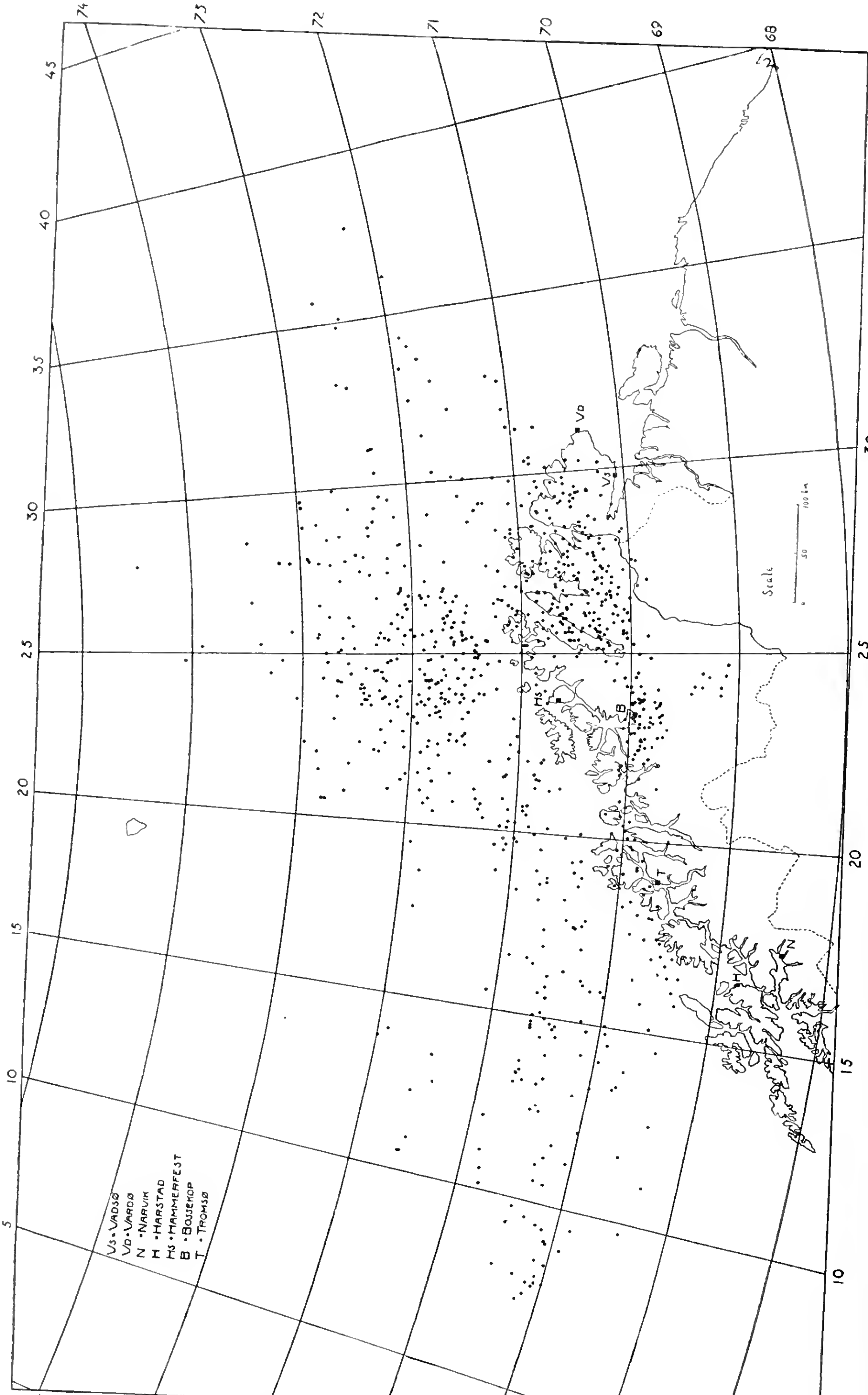

Vs · Vadsø
Vd · Vardø
N · Narvik
H · Harstad
Hs · Hammerfest
B · Bossekop
T · Tromsø
Scale

Fig. 2.

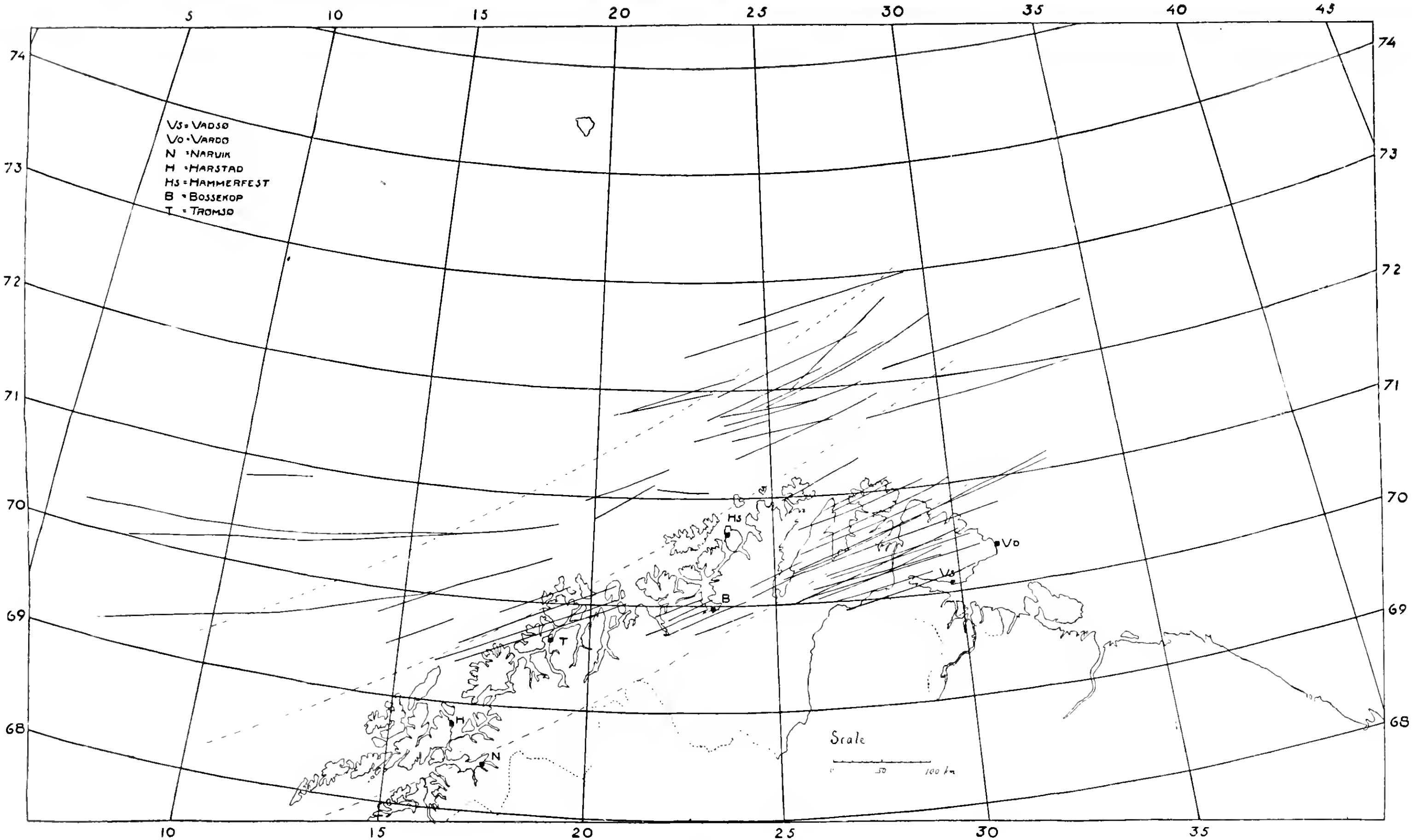

Vs = Vadsø
Vo = Vardø
N = Narvik
H = Harstad
Hs = Hammerfest
B = Bossekop
T = Tromsø
Hs
B
T
H
N
Vo
Vs
Scale
50
100 km
5
10
15
20
25
30
35
40
45
74
73
72
71
70
69
68

Fig. 3.

In the region of the 100 km. level *two accumulations are seen, one at an altitude of about* 101 *km., and the other at about* 106 *km.*, indicating, presumably, the lower limits of pronounced kinds of auroral corpuscles. The high altitudes above 200 km. are due to auroral rays in two curtains of March 14, $8^h\ 9^m$ and $8^h\ 27^m$, Central European time.

For each auroral point, the point on the surface of the Earth lying in the same Earth-radius has been found. The distribution of all these points is shown in Fig. 2. The northwestern points are mainly owing to auroras in the early part of the night, the south-eastern, lying over the country, to auroras about midnight and later.

The material obtained was very opportune for the drawing of the arcs and bands. In Fig. 3 are seen several of them; the almost parallel directions over the country from Tromsö to Vadsö are because of a most remarkable series of auroral bands from south-west to northeast through the zenith on the night of March 15 and 16. We got about 16 successful photograms of these bands, two of which will be mentioned later on.

In Fig. 3 are also seen circles with centers in the magnetic axis of the Earth for the year 1913. This axis cuts the Earth's surface in two diametrically opposite points, the northern of which, by the formulæ of Carlheim Gyllensköld, is in latitude 78°.9 N., and longitude 72°.4 west of Greenwich. The circles are respectively 22°, 23°, and 24° from this point.

The positions of the auroral bands with respect to these circles are of great importance in the determination of the nature of the aurora, and will be returned to when the investigation of the entire available material is completed.

2. Let us now mention some remarkable photograms taken the night of March 14 and 15. The first one represents two auroral curtains at $7^h\ 59^m$, March 14, 1913. The photograms are reproduced in Plate III. In the background is seen the constellation Cepheus.

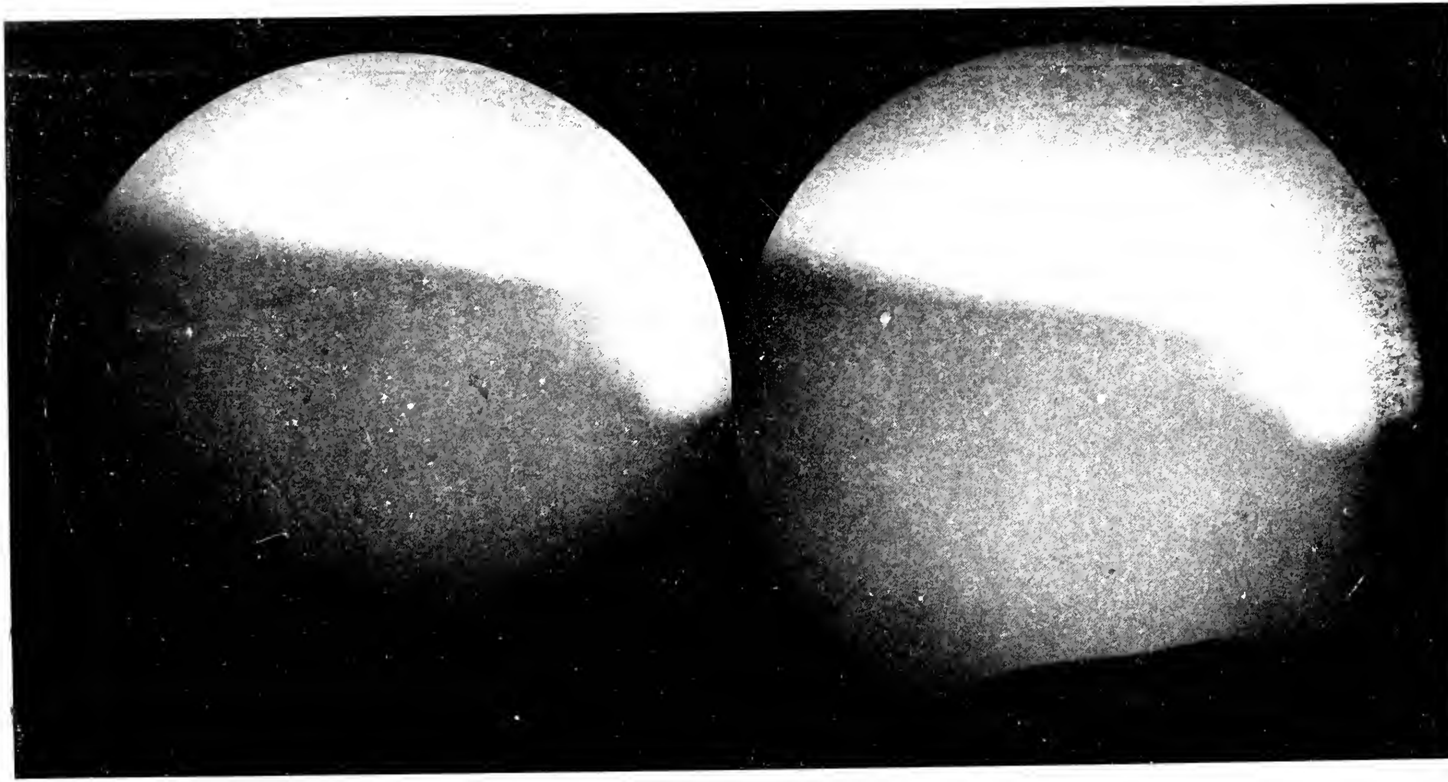
Fig. 4 is a sketch of the chosen points, numbered from 1 to 7. Each point is connected by a dotted line with the corresponding position of the same point seen from the other station, Store Korsnes, 27½ km. north of Bossekop, the length of this line thus producing the parallax. The altitudes of these points are in kilometers:

Number....................	1	2	3	4	5	6	7
Altitude....................	95	101	101	107	113	101	111

Their respective positions projected on the surface of the Earth are shown in Fig. 5.

Photographed from Store Korsnes. Photographed from Bosekop.

AURORA WITH CEPHEUS, MARCH 14, 7h 59m, 1913



Photographed from Store Korsnes. Photographed from Bossekop.]

AURORA WITH VEGA, MARCH 14, $8^h\ 02^m$, 1913.

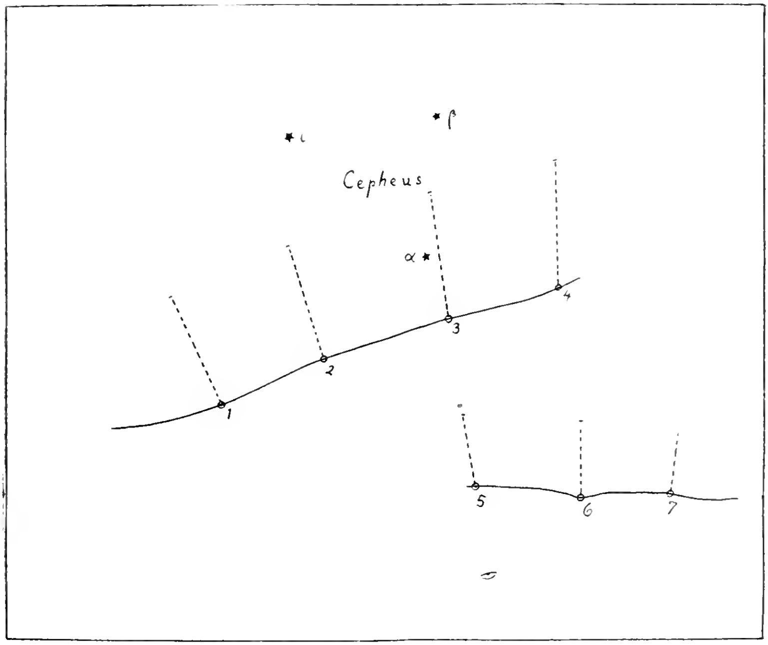

Cepheus
1
2
3
4
5
6
7

FIG. 4.

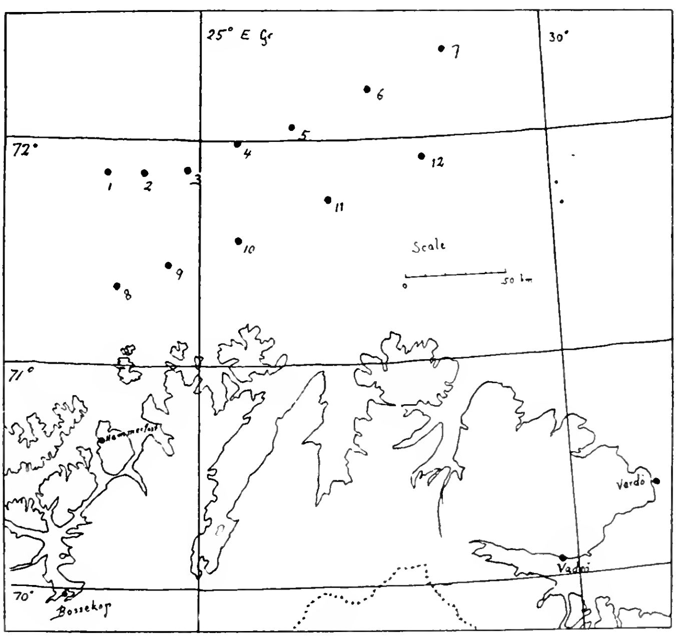

25° E Gr
30°
72°
71°
70°
1
2
3
4
5
6
7
8
9
10
11
12
Scale
0
50 km
Vardö
Vadsö
Bossekop
Hammerfest

FIG. 5.

The next photogram is of the same aurora at $8^h\ 2^m$. (See Plate IV and the corresponding sketch in Fig. 6.) The altitudes in kilometers are here:

Number	1	2	3	4
Altitude	112	111	108	108

From the positions (see Fig. 7), it is obvious that the points belong to the same curtain as the numbers 5, 6, 7 of the preceding photogram.

During the succeeding 30 minutes the western part of this aurora developed more and more in a splendid way; in plate V is seen a photogram, taken at $8^h\ 9^m$, by my assistants, B. J. Birkeland and Ottem. Venus and the constellation Aries are seen in the background. In the picture taken at Store Korsnes, a cloud is seen over the central part of the aurora, but not disturbing in any essential way the measurements of the parallax. The most remarkable feature of this aurora is its southern edge, stretching like an auroral ray almost from the horizon up to about 30°. This edge is owing to the fact that we are looking at the curtain tangentially, hence the luminous effect of the faint upper part is considerably strengthened.

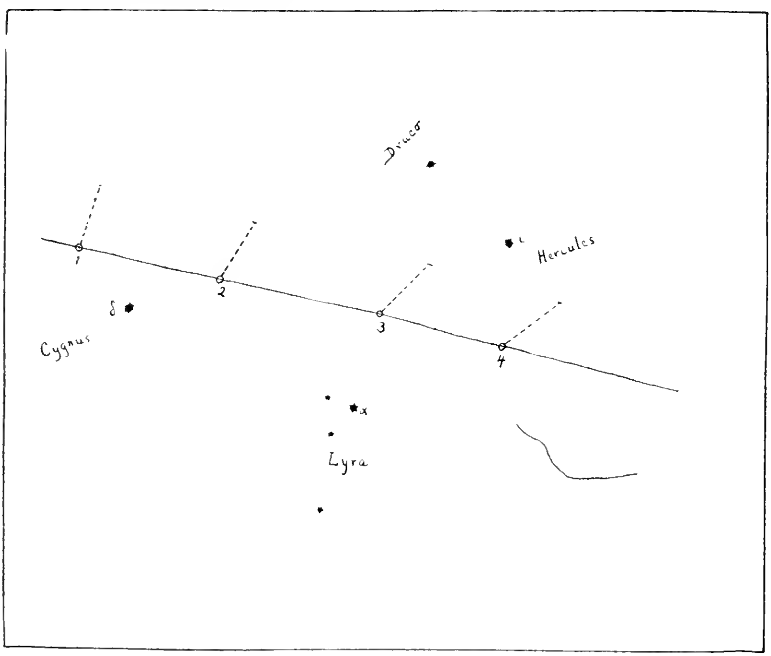


FIG. 6.

Photographed from Bossekop. Photographed from Store Korsnes.

Aurora with Venus, March 14, $8^h 3^m 09^s$, 1913.

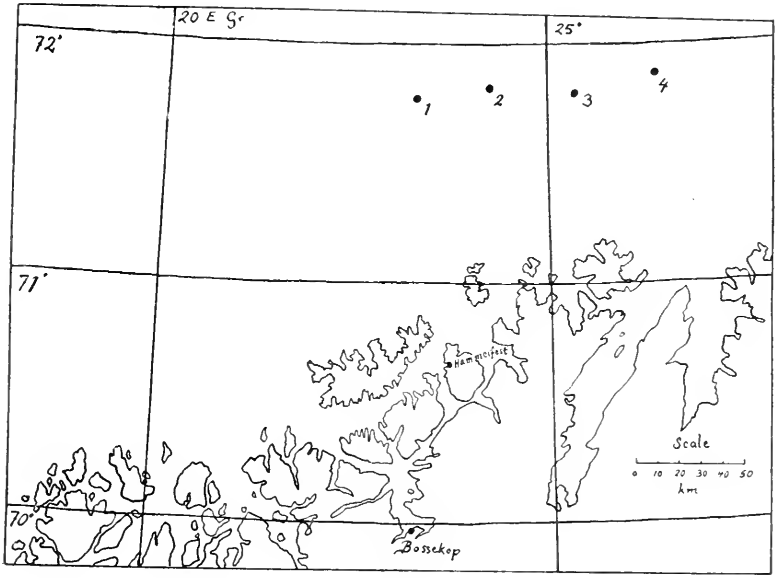


FIG. 7.

Fig. 8 is a sketch of the aurora, and in Fig. 9 the points are projected on the Earth's surface. The altitudes in kilometers here are:

Number....	1	2	3	4	5	6	7	8	9	10	11	12
Altitude....	319	282	242	181	149	118	108	114	108	117	117	112
Number....	13	14	15	16	17	18	19	20	21	22	23	24
Altitude....	107	106	103	115	127	130	109	115	120	111	116	125

In the first communication,[1] I mentioned some photographs taken with a prism-objective. One of those pictures of the aurora at $8^h\ 9^m$, is seen in Plate VI. It was taken simultaneously with the photogram at Bossekop; there can be distinguished different pictures of the sharp edge, corresponding to different spectral lines; the continuous spectrum of the planet Venus is seen in the middle. The camera with its prism was mounted on the aurora picture camera, as seen in this plate.

The possibility of taking prism-objective pictures with only a few seconds exposure will probably become of importance in the investigation of the composition of the air at great altitudes, because a sudden change of the spectrum along an auroral ray (corresponding to different colors) combined with photograms giving the altitude, will furnish information on the thickness of layers of different composition in the atmosphere. It will then be necessary to have spectra for comparison on the same plate.

A subsequent development of the same aurora is seen in Pl. VII, already published in the *Meteorologische Zeitschrift*, August,

[1] *Terr. Mag.*, vol. 18, pp. 133-135, Sept., 1913.

1913.[2] It represents the photograms also taken by B. J. Birkeland and Ottem, at $8^h\ 27^m$. We have here a remarkable auroral ray caused by the enhancement of light in directions tangential to the curtain, and marked by the numbers 19, 20, 21, 22, and 23 in Fig. 10, p. 168. The altitudes in kilometers here are:

Number...	1	2	3	4	5	6	7	8	9	10
Altitude...	103	113	102	100	100	111	99	106	111	106
Number...	11	12	13	14	15	16	17	18	19	20
Altitude...	96	98	100	99	101	116	119	127	139	169
Number...	21	22	23	24	25	26	27	28	29	30
Altitude...	203	232	265	117	111	107	103	102	112	115

[2] See also MÜLLER-POUILLET: *Lehrbuch der Physik und Meteorologie* 10te Auflage (1914), Vierter Band Fünftes Buch, Magnetismus und Electricität, Zweite und dritte Abteilung, p. 1376.

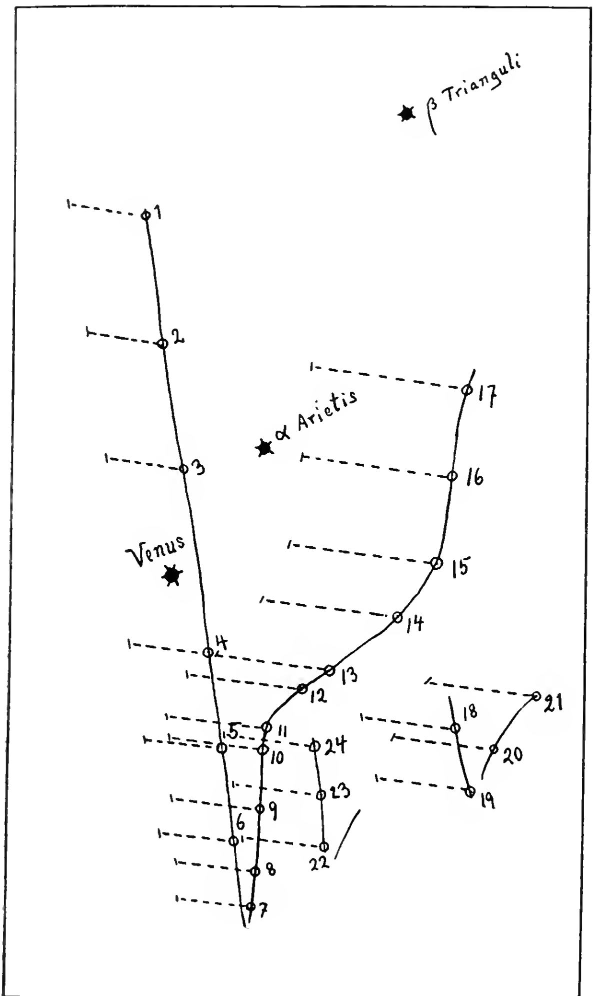


FIG. 8.

Photographed from Bossekop. Photographed from Store Korsnes.

AURORA WITH VENUS, MARCH 14, 8h 27m, 1913.

Photographed from Bossekop.

Photographed from Store Korsnes.

Aurora with the Great Bear, March 14, $14^{h}\ 26^{m}$, 1913.

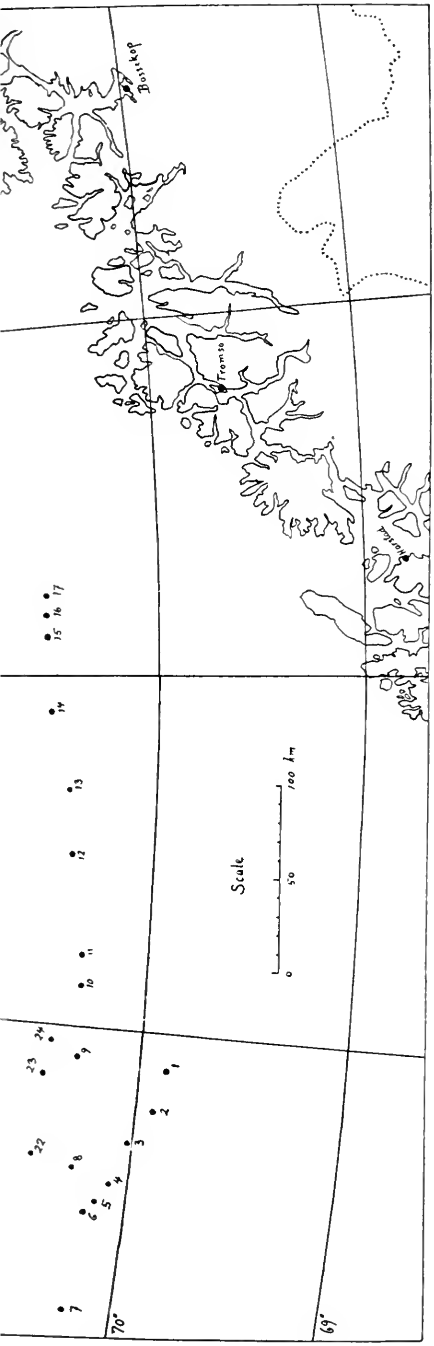

Bossekop
Tromsö
Scale
0
50
100 km
70°
69°

FIG. 9.

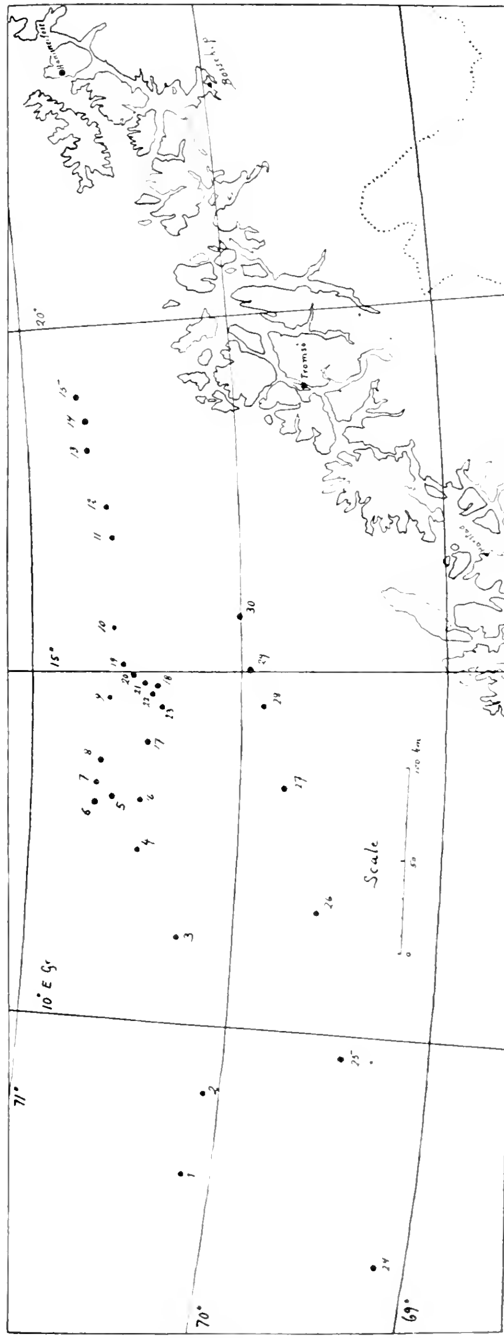

Hammerfest
Bossekop
Tromsö
20°
15°
10° E Gr
71°
70°
69°
Scale
0
50

FIG. 11.

The positions of the projected points are seen in Fig. 11, p. 167. The auroral display during the night of March 14 and 15 was terminated by a very strong coruscation; luminous patches appeared suddenly, vanished a few seconds later on, and reappeared again almost at the same place. A photogram of this coruscation at $14^h\ 26^m$ was published in the *Bulletin de la Société Astronomique de France* for November, 1913. This photogram is shown in Plate VIII, and Fig. 12 is a sketch of it. The parallax here is very large, from 14 to 15 degrees, which gives good determinations of altitude. The results in kilometers are:

Number..............	1	2	3	4	5	6	7
Altitude..............	91	94	99	95	94	99	98

The positions of the projected points are seen in Fig. 13.

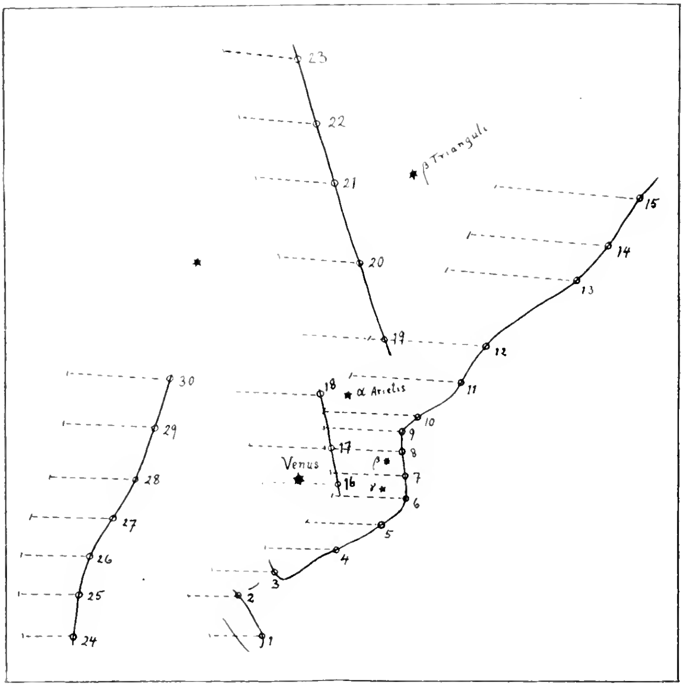


FIG. 10.

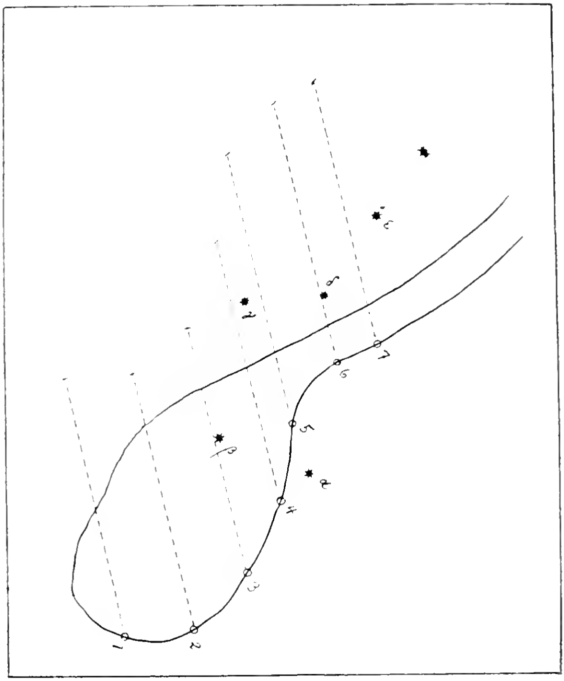


FIG. 12.

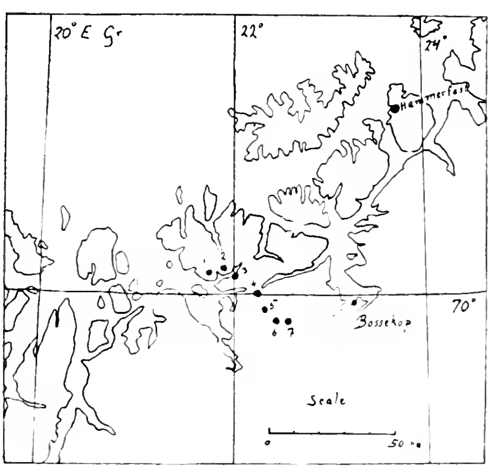


FIG. 13.

3. We shall now deal with some interesting photographs of the night of March 15 and 16, 1913. We have first a very interesting double arc at $8^h\ 6^m$; the photograms are seen in Pl. IX, and Fig. 14 gives the corresponding sketch. The altitudes in kilometers are:

Number....	1	2	3	4	5	6	7	8	9	10	11	12
Altitude....	109	106	104	108	109	111	109	120	122	122	126	129

Thus the southern arc had its lower border higher than the northern, a very interesting fact. The positions of the projected points are seen in Fig. 15.

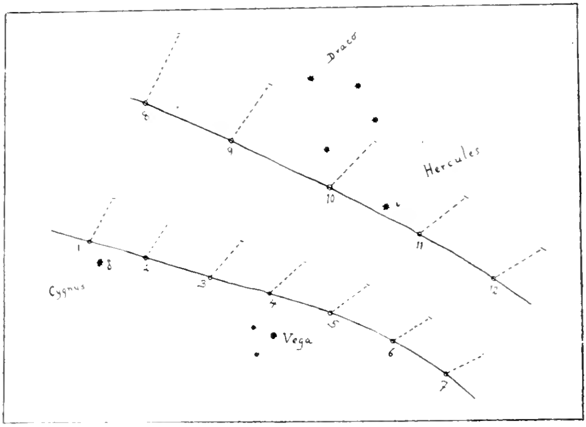


FIG. 14.

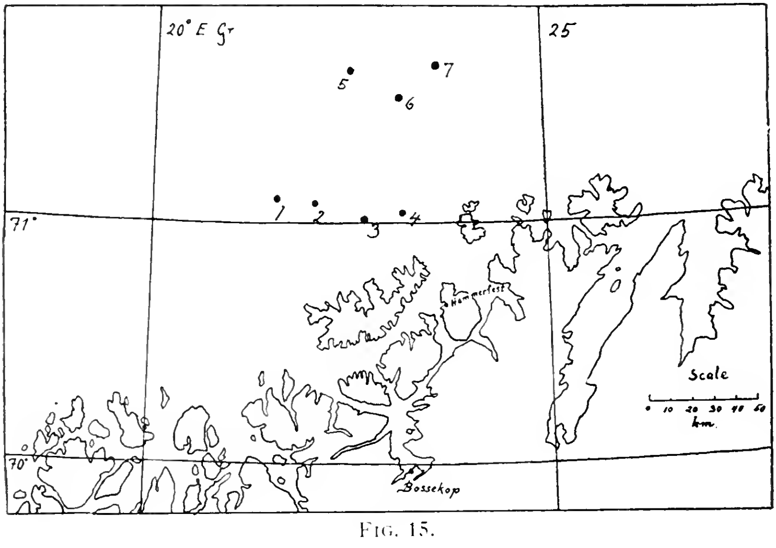
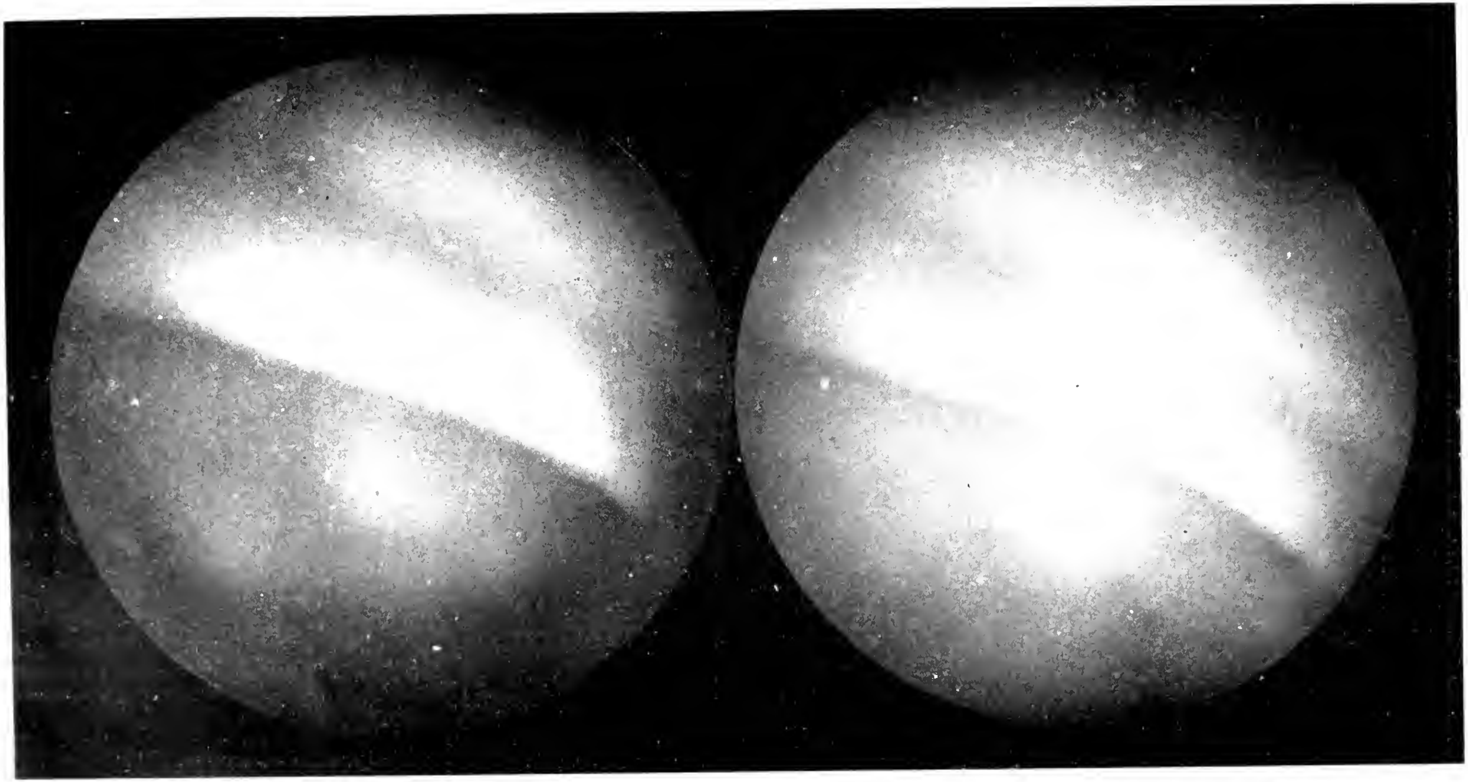
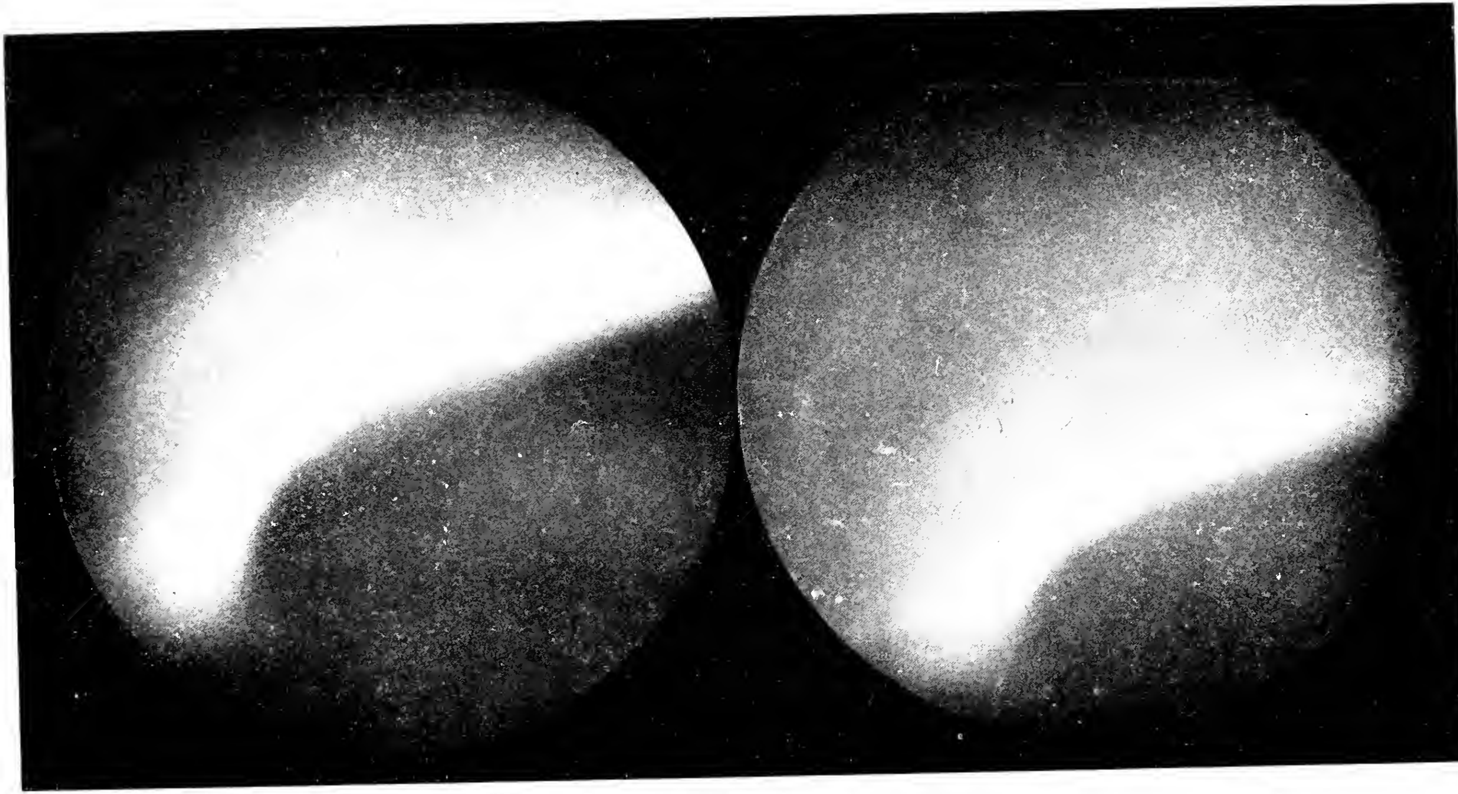


FIG. 15.



Photographed from Store Korsnes. Photographed from Bossekop

AURORA WITH VEGA, MARCH 15, 8^h 06^m, 1913.



Photographed from Store Korsnes. Photographed from Bossekop.

AURORA WITH CASSIOPEIA, MARCH 15, 9^h 17^m, 1913.

Another very pronounced arc at 9^h 17^m is seen in Pl. X (3 seconds exposure). Immediately afterward this arc changed into rapidly shifting colored rays and curtains. The sketch is seen in Fig. 16. Here the altitudes in kilometers are:

Number......	1	2	3	4	5	6	7
Altitude......	103	101	96	97	100	106	113

The projected positions are seen in Fig. 17.

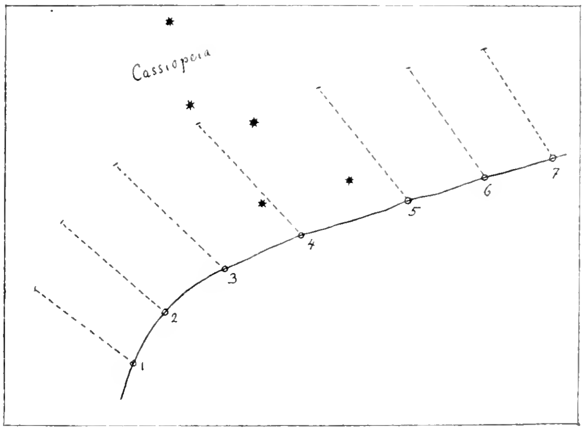


Fig. 16.

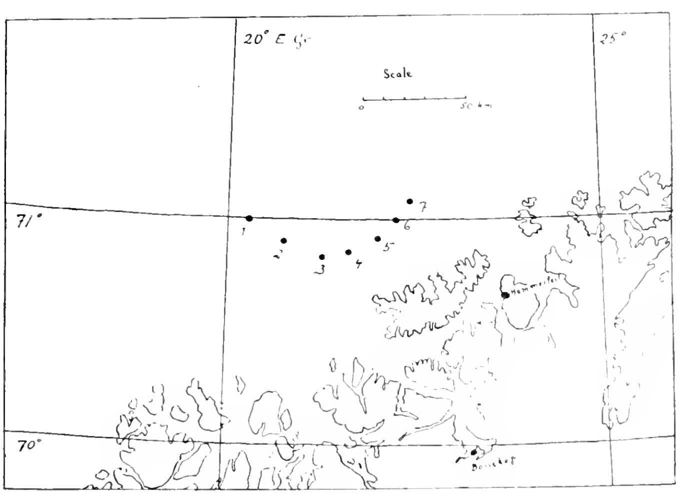


Fig. 17.

Now we shall consider some very interesting photograms of the auroral bands previously mentioned. The first one was taken by B. J. Birkeland and Ottem at $12^h\ 49^m$, and can be seen in Pl. XI; the other one, at $12^h\ 58^m$, is given in Pl. XII. Here the effect of the moon can be seen as luminous rings on the right side of the picture; it has nothing to do with the aurora. A sketch of the picture $12^h\ 49^m$ is seem in Fig. 18. The computed altitudes in kilometers here are:

Number........	1	2	3	4	5	6	7	8	9	10	11
Altitude........	108	107	108	109	107	166	104	104	106	111	110
Number........	12	13	14	15	16	17	18	19	20	21	22
Altitude........	108	111	115	118	116	111	111	116	118	118	100
Number........	23	24	25	26	27	28	29	30	31	32	33
Altitude........	98	99	99	101	102	104	99	100	99	98	101

The projected points show very nicely a series of parallel bands, as seen in Fig. 19 (the right side).

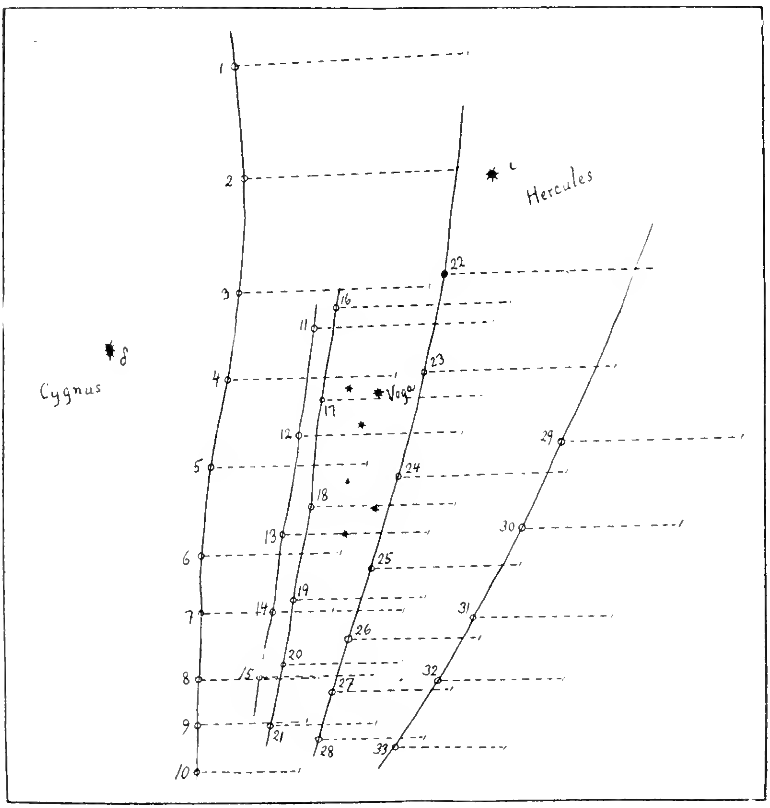
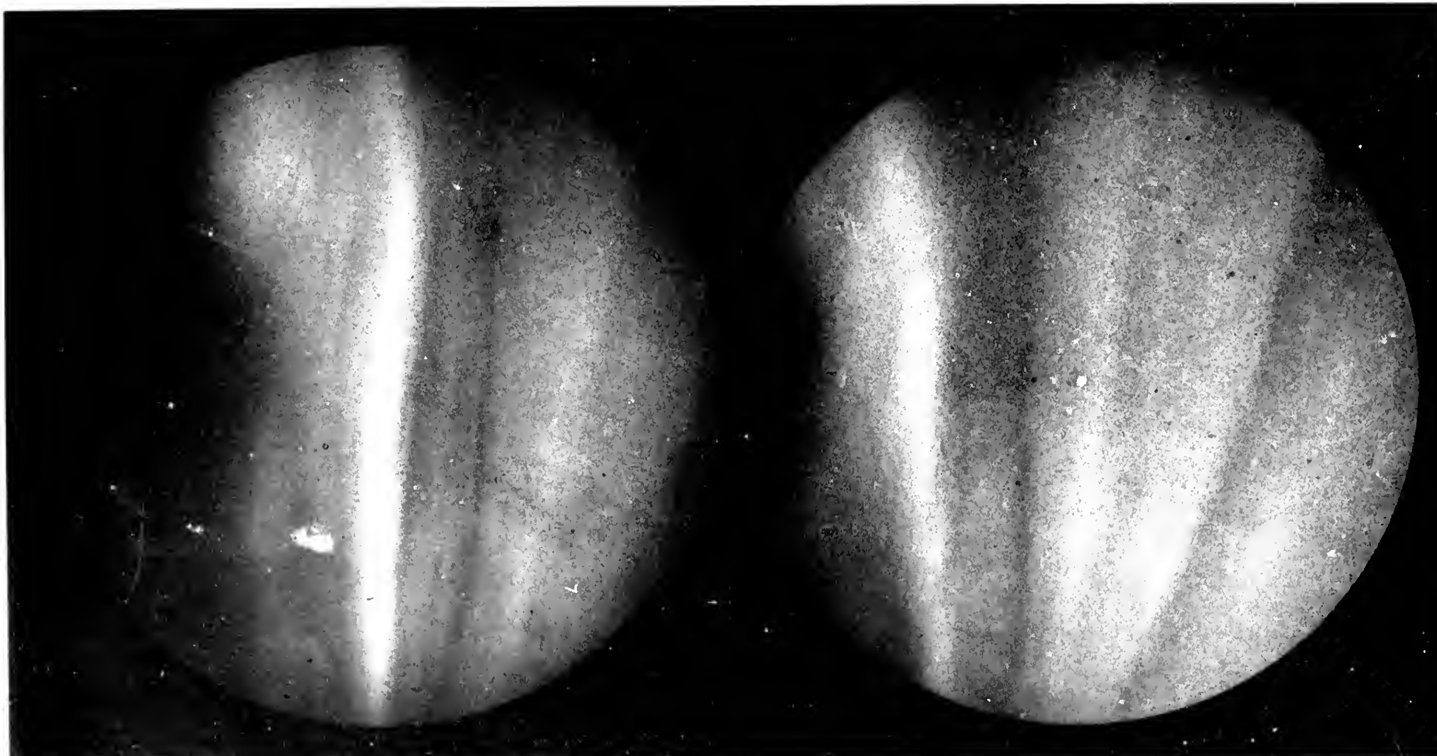
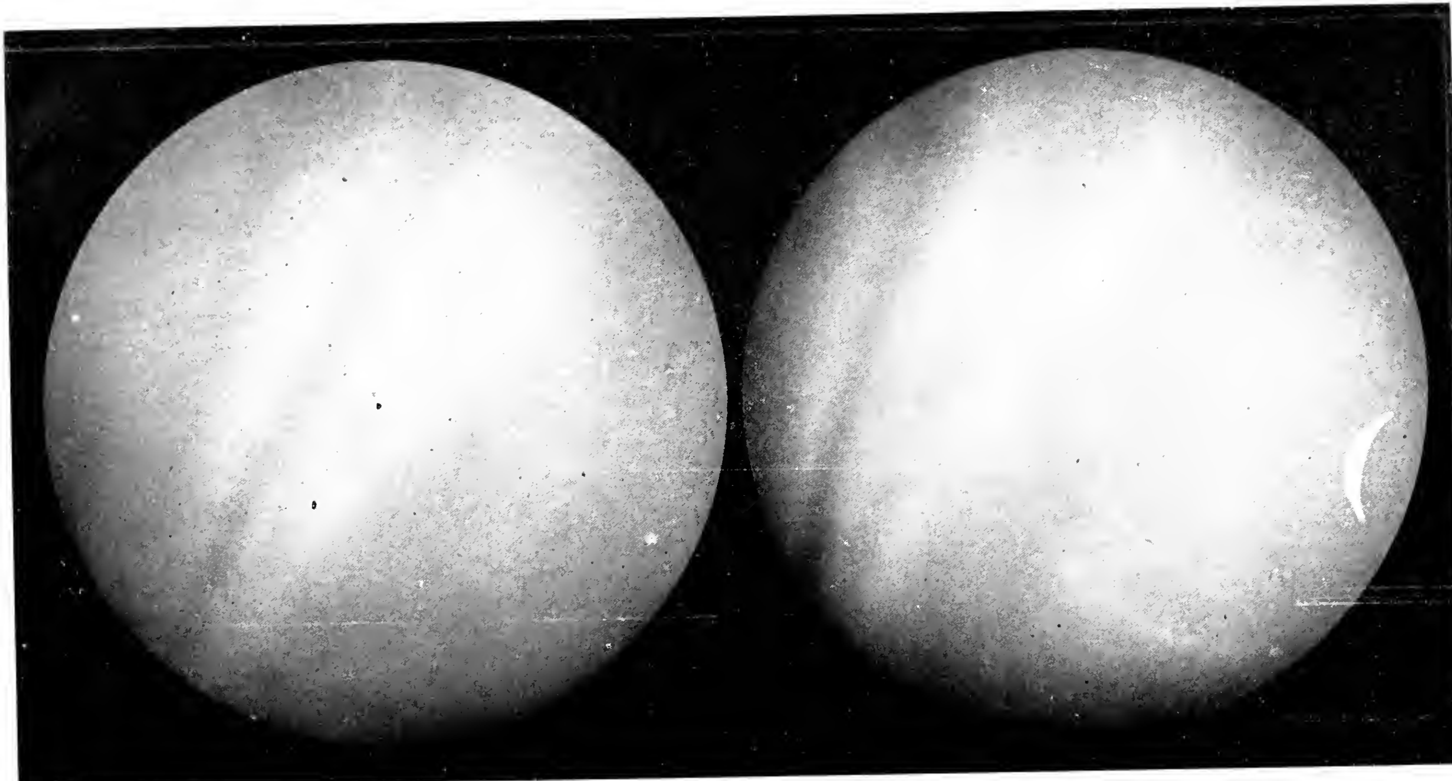


FIG. 18.



Photographed from Store Korsnes. Photographed from Bossekop.

AURORA WITH VEGA, MARCH 15, 12h 49m, 1913.



Photographed from Bossekop. Photographed from Store Korsnes.

AURORA WITH GEMINI, MARCH 15, 12h 58m, 1913.

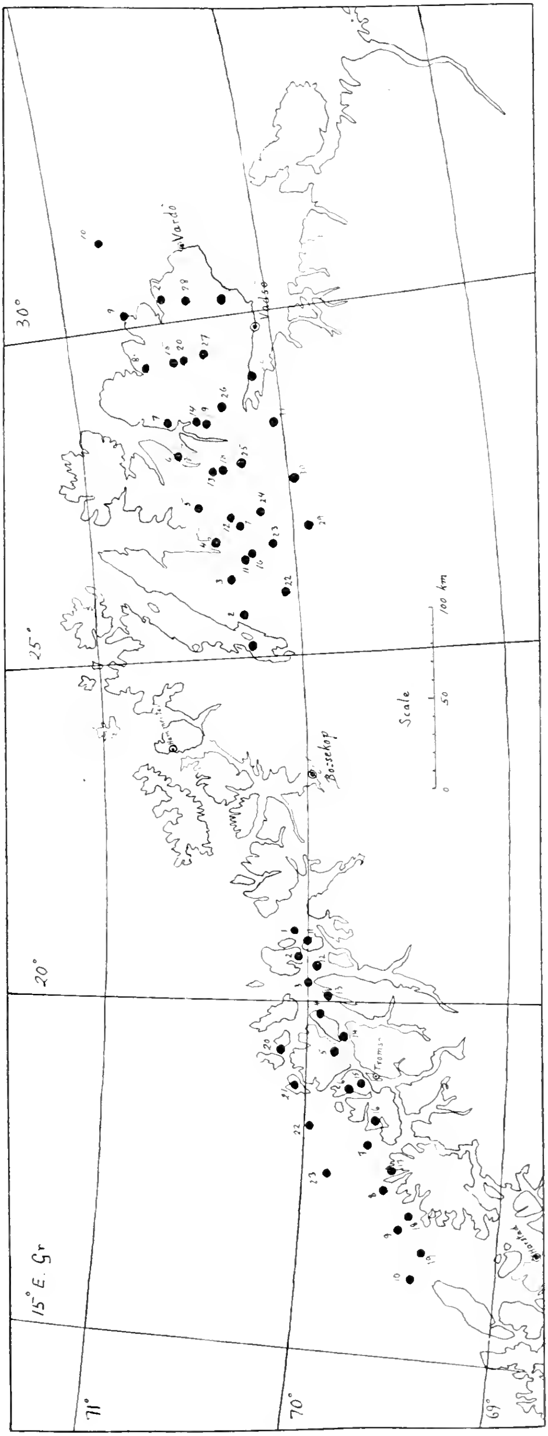

Vardö
Vadsö
Bosekop
Tromsö
Scale
0
50
100 km
30°
25°
20°
15° E. Gr
71°
70°
69°

FIG. 19.

Fig. 20 shows a sketch of the photograms at $12^h\ 58^m$. There the altitudes in kilometers are:

Number....	1	2	3	4	5	6	7	8	9	10	11	12
Altitude....	91	94	94	94	95	95	96	95	93	93	92	94
Number.....		13	14	15	16	17	18	19	20	21	22	23
Altitude.....		94	97	99	96	94	92	90	93	96	99	99

Here also the projected points are very beautifully arranged as parallel bands, as seen on the left side of Fig. 19.

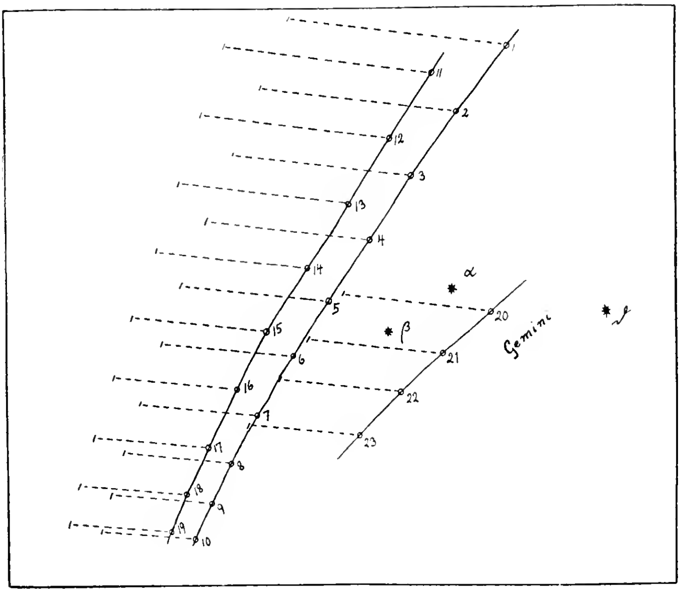


FIG. 20.

SUR LE CHAMP ÉLECTRIQUE DE L'ATMOSPHÈRE À RIO DE JANEIRO.

Par H. Morize.

Depuis longtemps déjà, des tentatives ont été faites à l'Observatoire de Rio de Janeiro, dans le but d'obtenir des données continues sur le potentiel électrique de l'atmosphère; mais, par suite de ressources insuffisantes, aussi bien en matériel qu'en personnel, les résultats obtenus n'ont servi qu'à montrer les difficultés à vaincre.

Ce n'est qu'en 1909, après l'acquisition d'un électromètre enregistreur de Benndorf et d'un disque radioactif Armet de Lisle, que les observations régulières ont pû commencer. Les difficultés rencontrées ont été tout d'abord le manque d'une place appropriée et l'inconstance de l'isolement, due à l'élévation du degré hygrométrique de l'air, et à de petites araignées qui établissent des courts-circuits difficiles à localiser. Une autre cause, heureusement peu fréquente, provient de petites étincelles qui passent de la borne d'entrée à la caisse extérieure de l'appareil, quand, durant des orages, le potentiel devient très élevé. Ces étincelles lèchent la surface de l'isolateur d'ambre et laissent une couche d'oxyde presqu'invisible, qui lui fait perdre ses qualités isolantes, jusqu'à ce qu'un nettoyage complet l'ait enlevée.

Le fontionnement de l'electromètre tel qu'il est venu du constructeur, laissait à désirer et m'a porté à introduire quelques petites modifications qui se sont montrées satisfaisantes à l'usage. La première consiste dans l'abandon de l'acide sulfurique pour produire l'amortissement et le desséchement de l'appareil. Dans un climat humide comme celui de Rio, l'acide augmente rapidement de volume et oblige à des substitutions fréquentes et dangereuses. D'un autre côté, son action desséchante ne peut pas être efficace, car une moitié de chaque isolateur se trouve sur la face extérieure de la caisse, et, partant, ne peut être desséchée. Quant à l'amortissement, après quelques essais, je me suis arrêté à la glycérine, recouverte d'une mince couche d'huile minérale non volatile, pour la préserver de l'humidité. De cette façon, l'amor-

tissement est suffisant et le liquide peut rester pendant des mois et même pendant une année, sans qu'il soit nécessaire de le changer. Si, par hasard, il y a lieu de dessécher l'intérieur de la boîte, on emploie temporairement un morceau de sodium.

Une autre modification s'est montrée utile. Dans la forme originale de l'électromètre, l'impression de la courbe se fait moyennant un choc du stylet (Fig. 1), qui représente le prolongement de l'aiguille, sur une feuille de papier sans fin, au travers d'un ruban de papier chimique se déroulant perpendiculairement au papier blanc, le long d'une tige d'acier, AB, dont le croisement avec le stylet détermine un point du tracé. Il résulte de cette disposition que, quand le stylet frappe sur le papier chimique du côté par lequel celui-ci entre sur le papier blanc, la courbe est très visible, parce que le papier chimique est alors neuf et fortement chargé en couleur; mais si le stylet, à cause d'un changement de la valeur du potentiel, se déplace du côté A (Fig. 1), l'inscription est à peine visible, parce que le stylet frappe à travers d'un papier chimique déjà épuisé. Or, la partie utilisée de ce papier est très étroite, étant moins d'un millimètre au milieu du ruban, sur une largeur totale d'un centimètre, par conséquent les bords conservent une

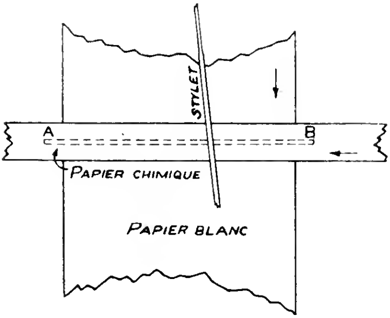


FIG. 1.

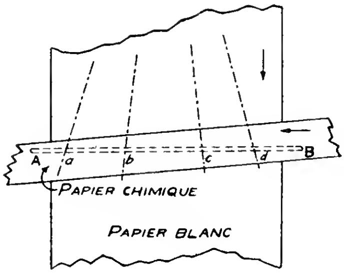


FIG. 2.

grande quantité de matière colorante inutile. Si donc le ruban se déroulait un peu obliquement, au lieu d'être normal au papier blanc, toute la largeur du papier chimique pourrait être employée et on aurait une égale intensité d'impression sur toute la courbe, comme le montre la Fig. 2, où à chaque position a, b, c, d, du stylet, correspond une zône, à part, du ruban de papier chimique. De cette manière, le tracé du diagramme est partout également intense et facilement lisible.

On emploie comme collecteur, un disque de cuivre recouvert par un centigramme de sulfate de radium, d'activité égale à 100,000 incorporé dans un vernis insoluble. Le disque a été fourni par la maison Armet de Lisle, de Paris, en 1910, et manifeste une grande intensité qui est toujours la même car l'électromètre étant artificiellement déchargé, son potentiel revient à sa valeur primitive en quelques secondes.

Le disque radioactif est maintenu horizontalement, sa face active *AB* tournée vers le sol (Fig. 3), à 5 cm. au-dessus d'une épaisse plaque de cuivre *CD*. La tranche d'air qui sépare cette plaque et le disque est la zône dans laquelle s'opère l'ionisation, et c'est à sa hauteur moyenne que se rapporte la prise de potentiel.

La plaque *CD* est suffisamment épaisse et sa distance à l'isolateur d'ébonite *H* est assez grande, pour que les rayons pénétrants

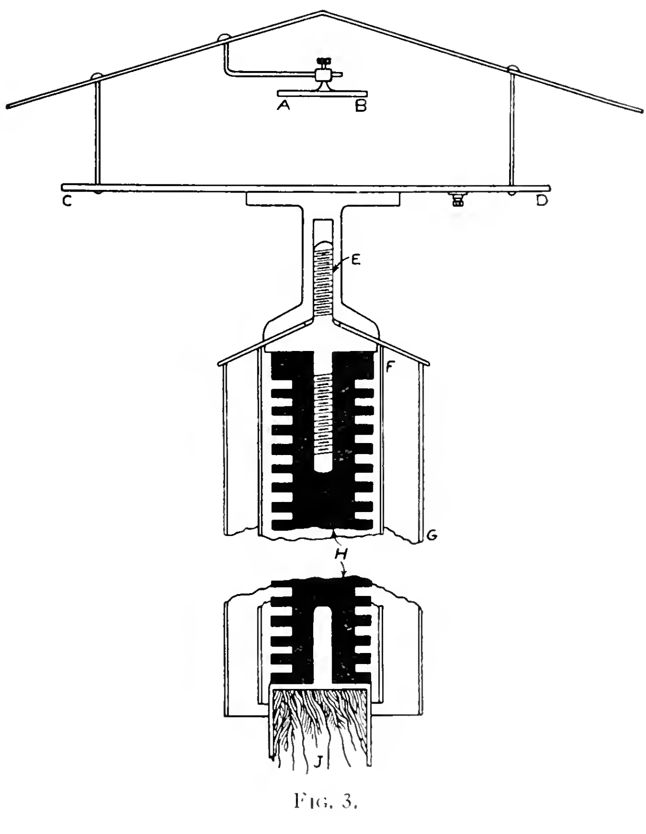


Fig. 3.

partis de *A B* ne puissent arriver jusqu'à l'air entre l'ébonite et les tubes protecteurs *F* et *G*. De cette façon, les pertes de charge sont insensibles aussi longtemps que la poussière et les petites araignées respectent l'isolateur. Une toiture préserve le disque de radium contre la pluie. L'enveloppe G produit le même effet quant au support isolant, tandis que le tube F, très rapproché de l'ébonite, rend difficile l'entrée des poussières. La connection du collecteur avec l'électromètre a lieu par un fil conducteur qui pénètre dans la guérite de l'enregistreur au travers d'un bouchon d'ébonite fixé au milieu d'une vitre et abrité contre la pluie au moyen d'un petit auvent.

Cet isolateur d'entrée a été complété, après beaucoup d'essais, par M. Alix Lemos, Ing. Civ., Assistant de 1ère classe, qui a pris à sa charge l'instrument, ainsi que son étalonnage et la réduction des diagrammes.

L'étalonnage s'éxécute à l'aide de piles de Krueger, fournies par la Maison Spindler & Hoyer, de Göttingen. Chaque boîte contient, isolés dans un bloc de paraffine, 100 petits éléments de Weston, qu'on peut relier en parallèle ou en série. On met alternativement le pôle + ou le pôle-des 100 éléments, reliés en série, en contact avec l'aiguille del' électromètre, tandis que le pôle opposé est mis à la terre, et on oblige alors l'aiguille à marquer un point sur le papier. On inverse alors la pile et on procède de même. La mi-distance entre les marques représente la place du zéro instrumental, tandis que le double du potentiel de la pile, divisé par l'intervalle en millimètres donne la valeur de l'échelle. On exécute journellement cette opération à midi, moyennant un commutateur inverseur bien isolé.

Ces piles, d'un emploi très commode, à cause de leur faible volume, se sont montrées d'une conservation très capricieuse. Leur vérification fréquente s'effectue avec des électromètres Wulf, fournis avec étalonnage, par la maison Günther & Tegetmeyer de Braunschweig. Ces instruments, ci ne se sont pas montrés très constants dans leurs indications, ce qui rend incertaine la valeur à attribuer à la force électromotrice des piles.

Parmis les différentes piles, celles qui portent les numéros 495 et 468 se sont montrées les plus constantes, et, pour ce motif, ont servi pour l'étalonnage. Pour la charge des quadrants, on en emploie deux autres, choisies aussi égales que possible et dont le milieu a été mis à la terre.

La réduction au plan des indications trouvées n'a malheureuse-

ment pas eu lieu. Dans l'emplacement de l'Observatoire actuel, ni dans son voisinage, on ne trouve nulle part une zône plane suffisament étendue pour que les observations puissent y être comparées à celles faites à l'Observatoire. Cette lacune est certainement très regrettable, mais n'empêche en rien de tirer des conclusions des valeurs relatives recueillies. Le collecteur se trouve sur un mât, facilement abattable, au bord de la terrasse SE de l'Observatoire, à une hauteur de 66 m. au-dessus du niveau de la mer, et 16 m. au-dessus de la cour de l'Observatoire, a 20 m. par rapport au sol extérieur, à 5, 10^{m} au-dessus de la terrasse et 4, 15^{m} sur le garde-fou en fer de celle-ci. Horizontalement, le mât se trouve à 2, 15^{m} du coin SE de la salle méridienne, qui n'a, à cette place, que 3, 20^{m} de hauteur. Le pavillon central dont le bord a 5, 0^{m} de haut, se trouve à la distance horizontale de 7, 60^{m} du collecteur. On n'a utilisé pour le calcul des moyennes horaires que les journées calmes, en suivant, pour cette distinction, les règles publiées dans le Rapport de la Conférence Météorologique d'Innsbruck en 1905. Le calcul des constantes harmoniques, ainsi que toutes les réductions, ont été faites, soit par M. Alix de Lemos lui-même, soit sous sa direction immédiate. Les tableaux I à IV montrent combien les belles journées sont rares à Rio, aussi, à cause de l'insuffisance du nombre de jours, M. Alix de Lemos s'est vu réduit à ne procéder à l'analyse harmonique pour les moyennes horaires, semestrales et annuelles, qu'en divisant l'année en deux périodes, le semestre de septembre à février, chaud et humide, et celui de mars à août, plus sec et relativement frais, des années 1910 1913.

La variation diurne de Rio manifeste des ressemblances à celle de Kremsmünster. (Fig. 4.) On note dans les moyennes trimestrielles une période simple, avec un minimum accentué entre 2^{h} et 3^{h} am., et un maximum, moins marqué, entre 10^{h} am. et midi, qui se manifestent aussi dans les moyennes annuelles par un minimum à 3^{h} et un maximum à midi. Cette oscillation, très nette en 1911 1912, est beaucoup moins sensible dans les observations de 1913, à cause de démolitions et de reconstructions prolongées dans un hôpital mitoyen à l'Est, qui ont occasionné des poussières ayant une mauvaise influence sur le fonctionnement de l'électromètre. Tout d'abord, ces poussières ont rendu précaire l'isolement du collecteur et de l'isolateur d'entrée, et ont aussi fortement troublé le champ, ainsi que le révèle le simple examen des moyennes horaires de l'année.

La variation annuelle que MM. Rey et Rouch ont signalée dans leur rapport du voyage antarctique du "Pourquoi Pas" et qu'ils attribuent à la position du Soleil sur l'écliptique, n'est pas sensible dans nos observations.

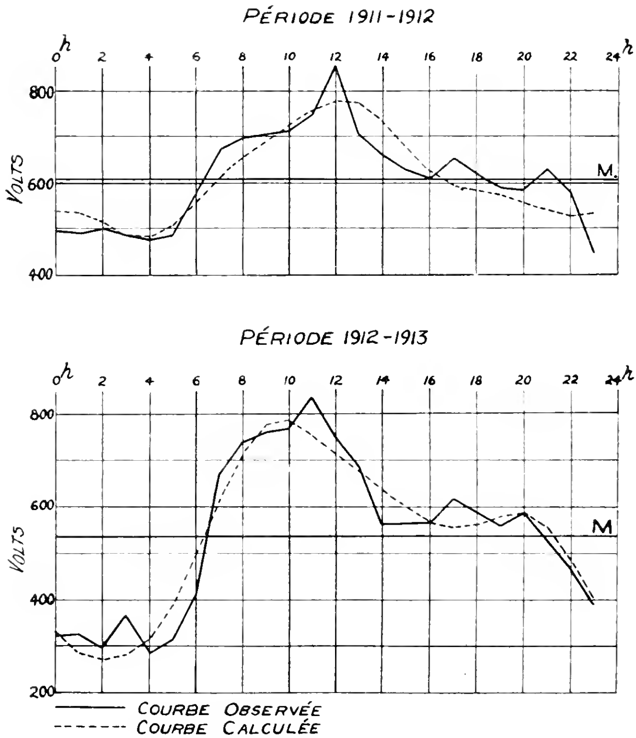


Fig. 4.

À propos des facteurs météorologiques auxquels on attribue d'ordinaire une grande influence sur la valeur du champ, on peut dire que les phénomènes aqueux, tels que la pluie, la bruine, le brouillard, ainsi que les orages, rendent généralement le champ négatif, mais que les exceptions ne sont pas rares. Les phénomènes électriques qui accompagnent les orages ont naturellement une influence plus marquée et non seulement le potentiel acquiert des valeurs extrêmement élevées, mais encore on observe des changements de signe rapides et accentués. Il est commun de voir alors le stylet de l'électromètre sortir des limites du papier, aussi bien du côté positif que du côté négatif.

Quand la nébulosité est forte, elle abaisse le potentiel, principalement si elle est constituée par des St-Cu. La présence des Cu-N produit habituellement l'inversion du champ, tandis que celle des Ci élève de beaucoup la valeur de celui-ci, tout en le maintenant positif.

L'influence de la pression barométrique doit être faible, car on n'a pu la reconnaître; quant à l'influence de l'humidité, soit-ce d'une façon directe, ou bien simplement par sa tendance à diminuer l'isolement de l'électromètre, le fait est qu'elle diminue très sensiblement le potentiel.

Le vent dominant à Rio est le SSE, venant de la mer et augmentant l'humidité, aussi peut-on dire, d'une façon générale, qu'il abaisse la valeur du potentiel.

Observatoire National de Rio de Janeiro,
10 *octobre* 1915.

TABLEAU 1. ÉLECTRICITÉ ATMOSPHÉRIQUE; MOYENNES HORAIRES.

	0^h	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1ère Période	590	450	502	427	459	483	556	709	757	812	831	866	717	677	554	632	661	678	586	444	471	511	610	553
2ème "	438	364	341	379	405	440	625	1005	1054	1126	1208	1055	813	668	617	603	536	615	592	601	533	550	599	538
3ème "	573	518	515	523	569	572	638	828	854	916	914	1056	1139	897	801	752	746	720	577	677	634	668	656	607
4ème "	757	700	628	635	665	852	763	911	1056	1018	1032	1048	1030	947	718	782	770	735	749	853	766	788	918	965
1ère et 2ème "	514	407	422	403	432	462	591	857	906	969	1020	961	765	673	586	618	599	647	589	523	502	531	605	546
3ème et 4ème "	665	609	572	579	617	712	701	870	955	967	973	1052	1085	922	760	767	758	728	663	765	700	728	787	786
Année	590	508	497	491	525	587	646	864	931	968	997	1007	925	798	673	693	679	688	626	644	601	630	696	666

1ère et 2ème Période......Septembre 1910 à Février 1911.
3ème et 4ème Période......Mars 1911 à Août 1911.

Nombre des jours calmes et beaux: Dans la 1ère Période (Septembre à Novembre 1910), 12 jours.
" " " " " " : " " 2ème " (Décembre 1910 à Février 1911), 17 "
" " " " " " : " " 3ème " (Mars à Mai 1911), 12 "
" " " " " " : " " 4ème " (Juin à Août 1911), 15 "

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Tableau II. ELECTRICITE ATMOSPHÉRIQUE; MOYENNES HORAIRES.

		0h	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1ère	Période	498	522	525	517	*505*	523	669	850	826	847	881	877	*1050*	853	527	571	654	599	589	552	519	562	588	*304*
2ème	"	571	569	627	*553*	578	622	756	774	788	815	*885*	843	876	621	688	535	534	618	525	*433*	523	726	567	*157*
3ème	"	418	383	343	371	*312*	313	360	429	495	510	407	566	*742*	645	674	641	607	*759*	660	672	619	544	560	*177*
4ème	"	487	485	501	495	499	473	510	612	676	623	666	685	703	684	743	*759*	628	623	698	700	661	659	586	*158*
1ère et 2ème	"	535	546	570	535	*542*	573	713	812	807	831	883	860	*963*	737	608	553	594	609	557	493	521	644	578	*126*
3ème et 4ème	"	453	434	422	433	406	*393*	435	521	586	567	537	626	*723*	665	709	700	618	691	679	686	640	602	573	468
Année		494	490	499	484	474	483	574	667	697	699	710	743	*813*	701	659	627	606	650	618	590	581	623	576	*117*

1ère et 2ème Période.......Septembre 1911 à Février 1912.
3ème et 4ème Période......Mars 1912 à Août 1912.

Nombre des jours calmes et beaux: Dans la 1ère Période (Septembre à Novembre 1911), 5 jours.
" " " " " " : " " 2ème " (Décembre 1911 à Février 1912), 5 "
" " " " " " : " " 3ème " (Mars à Mai 1912), 7 "
" " " " " " : " " 4ème " (Juin à Août 1912), 16 "

TABLEAU III. ÉLECTRICITÉ ATMOSPHÉRIQUE; MOYENNES HORAIRES.

	0h	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1ère Période	238	273	324	501	217	225	475	866	813	646	529	715	621	521	506	511	577	554	669	546	575	330	189	212
2ème "	394	444	282	291	313	333	422	861	940	1091	1117	1127	880	813	478	595	709	625	580	552	578	560	527	435
3ème "	403	350	312	332	312	304	325	403	563	564	613	668	728	653	632	580	520	547	523	467	505	470	488	331
4ème "	250	241	277	347	295	390	413	526	622	734	803	832	776	747	629	573	447	736	558	671	677	752	662	584
1ère et 2ème "	316	359	303	396	265	279	449	864	877	869	823	921	750	667	492	553	643	590	625	549	577	445	358	324
3ème et 4ème "	327	296	295	339	304	347	369	465	593	649	708	750	752	700	631	577	484	642	541	569	591	611	575	458
Année	321	327	299	367	284	313	409	664	735	759	766	836	751	684	561	565	563	616	583	559	584	528	467	391

1ère et 2ème Période......Septembre 1912 à Février 1913.
3ème et 4ème Période......Mars 1913 à Août 1913.

Nombre des jours calmes et beaux: Dans la 1ère Période (Septembre à Novembre 1912), 7 jours.
" " " " " " : " " 2ème " (Décembre 1912 à Février 1913), 8 "
" " " " " " : " " 3ème " (Mars à Mai 1913), 23 "
" " " " " " : " " 4ème " (Juin à Août 1913), 9 "

Tableau IV. ÉLECTRICITÉ ATMOSPHÉRIQUE; MOYENNES HORAIRES.

	0^h	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1ère Période	367	418	386	518	603	705	821	1105	1203	1064	1311	904	739	626	582	628	678	681	466	559	524	431	485	423
2ème "	392	472	560	483	423	456	691	851	804	935	921	888	755	694	740	723	642	634	556	473	508	466	378	368
3ème "	309	276	303	299	324	226	242	627	500	563	769	752	742	492	480	447	505	480	489	548	484	440	652	214
4ème "	259	259	279	139	299	239	299	338	318	318	398	338	398	398	398	677	597	796	697	836	915	836	935	896
1ère et 2ème "	380	445	473	501	513	581	756	978	1004	1000	1116	896	747	660	661	676	660	658	511	516	516	449	432	396
3ème et 4ème "	284	268	291	219	312	233	271	483	409	441	584	545	570	445	439	562	551	638	593	692	700	638	794	555
Année	332	357	382	360	413	407	522	731	707	721	850	721	659	553	551	619	606	648	552	604	608	544	613	476

1ère et 2ème Période......Septembre 1913 à Février 1914.
3ème et 4ème Période......Mars 1914 à Août 1914.

Nombre des jours calmes et beaux: Dans la 1ère Période (Septembre à Novembre 1913), 9 jours.
" " " " " " : " " 2ème " (Décembre 1913 à Février 1914), 7 "
" " " " " " : " " 3ème " (Mars à Mai 1914), 5 "
" " " " " " : " " 4ème " (Juin à Août 1914), 16 "

TABLEAU V. COÉFFICIENTS HARMONIQUES, 1911 et 1912

$c_e = A_0 + A_1 \cos qt + B_1 \sin qt + A_2 \cos 2qt + B_2 \sin 2qt +$ [illegible] $q = 15$ [illegible]

1910 1911

1ère Période		
$A_0 = +\ 630.3$		
$A_1 = -\ 191.0$	$B_1 = +\ 56.1$	
$A_2 = +\ 23.1$	$B_2 = -\ 140.7$	
$A_4 = -\ 5.0$	$B_4 = -\ 28.6$	
$A_6 = -\ 7.9$	$B_6 = -\ 18.3$	
2de Période		
$A_0 = +\ 780.0$		
$A_1 = \ \ 152.9$	$B_1 = +\ 20.5$	
$A_2 = +\ 56.0$	$B_2 = -\ 101.1$	
$A_4 = +\ 19.5$	$B_4 = -\ 18.8$	
$A_6 = +\ 27.0$	$B_6 = -\ 12.8$	
Année		
$A_0 = +\ 705.4$		
$A_1 = -\ 172.0$	$B_1 = +\ 38.3$	
$A_2 = +\ 39.7$	$B_2 = -\ 120.9$	
$A_4 = +\ 7.2$	$B_4 = \ \ 23.7$	
$A_6 = +\ 9.7$	$B_6 = -\ 15.5$	

1911 1912

1ère Période	
$A_0 = +\ 645.7$	
$A_1 = -\ 144.1$	$B_1 = +\ 79.2$
$A_2 = +\ 32.5$	$B_2 = -\ 71.4$
$A_4 = +\ 14.9$	$B_4 = +\ 2.5$
$A_6 = +\ 3.9$	$B_6 = +\ 21.8$
2de Période	
$A_0 = +\ 565.3$	
$A_1 = -\ 95.0$	$B_1 \ \ 109.6$
$A_2 = -\ 2.3$	$B_2 = \ \ 21.0$
$A_4 = -\ 1.3$	$B_4 = \ \ 25.3$
$A_6 = +\ 5.9$	$B_6 = -\ 6.8$
Année	
$A_0 = +\ 605.6$	
$A_1 = -\ 119.6$	$B_1 = -\ 15.3$
$A_2 = +\ 15.0$	$B_2 = -\ 46.2$
$A_4 = +\ 6.7$	$B_4 = +\ 14.1$
$A_6 = +\ 4.9$	$B_6 = +\ 7.3$

MOYENNES MENSUELLES.

	Janvier	Février	Mars	Avril	Mai	Juin	Juillet	Août	Sept.	Octobre	Novembre	Décembre
1910									591	571	654	648
1911	690	625	696	860	613	843	582	1086	823	118	697	567
1912	925	444	461	608	495	612	598	616	568	364	523	648

NOTES

13. Personalia. *Pietro Baracchi* has resigned from the directorship of the Melbourne Observatory. *Eduard Brückner* has been elected president of the Vienna Geographical Society. *D. Berky*, who successfully led, for the Department of Terrestrial Magnetism, the magnetic expeditions across the desert of Sahara, 1912-1913, and through Central Brazil in 1915, from Rio de Janeiro to Para via Goyaz and down the Araquaya and Tocantins rivers, has accepted the Tyndall fellowship in physics at the University of Pennsylvania to enable him to complete his studies for the Ph. D. degree. *E. Kidson*, after successfully completing, for the Department of Terrestrial Magnetism, the general magnetic survey of Australia, 1911-1914, and a series of comparisons of magnetic standards, during 1915, at Washington, Kew, Greenwich, Stonyhurst and Eskdalemuir, has accepted a post with the British Meteorological Office for military field duty. *Otto Baschin* was awarded by the Royal Prussian Academy of Sciences the silver Leibnitz medal in recognition of his services to geography. *C. A. Angot* on January 19, 1916, will be presented with the Symons Memorial gold medal, awarded biennially by the Royal Meteorological Society for distinguished work in meteorology.

14. The *Carnegie*, after a continuous trip of 90 days from Dutch Harbor, Alaska, during which, under *J. P. Ault's* command, magnetic observations were made at over 200 sea-stations, arrived at Port Lyttleton, New Zealand, on November 2. On December 5 she sailed from this port to carry out a cruise of about 4 months, between the parallels of 55° and 60° south; her return to Port Lyttleton is expected in April, 1916.

15. We regret to be obliged to record the death of Sir Arthur Rücker, on November 3, 1915, in his sixty-seventh year. A portrait and biographical sketch were published in vol. IV (Pl. I, p. 71) of this Journal. Sir Arthur continued his kindly and stimulating interest in terrestrial-magnetic researches practically until the day of his death. He was a member of the Advisory Council of the Department of Terrestrial Magnetism from the time of its establishment, as also a member of the editorial staff of the Journal from the beginning. He will be greatly missed by all who had the privilege of knowing him.

ABSTRACTS AND REVIEWS

PALAZZO, L.: *Magnetic Observations in Eastern Africa.*[1]

In these publications Professor Palazzo presents the results of his magnetic observations in Italian Somaliland and British East Africa in the years 1908-10, and in Eritrea in the year 1913.

The first paper[1] begins with an introduction containing a short narrative of the journey, a description of the instruments used, and statements regarding the instrumental constants and the formulæ employed in the reductions. The main portion of the work gives in detail the descriptions of stations and reproductions of the original records and computations. The final results are then tabulated and reduced to the epoch 1909.0. Using these results and those of previous observers, values of the secular variation are obtained. In addition to his own results, Professor Palazzo gives also those obtained by officers of the Italian hydrographic vessel "Staffeta" at 7 stations in Italian Somaliland, and 1 station at Zanzibar, during service in the Indian Ocean in the years 1907-08 and 1911. There is also a discussion of the change of inclination with latitude, and a curve is traced showing the relation between the two. The paper concludes with a map of the region under consideration, with isogonic, isoclinic and isodynamic lines.

The second paper *(La carta magnetica del Benadir)* is a summary of the preceding, prepared as a monograph for presentation to the Italian Ministry of Foreign Affairs.

The third publication *(Misure magnetiche in Eritrea)*, after a short introduction, continues with a narrative of the journey in Eritrea during the summer of 1913. Then follow descriptions of the instruments used, a discussion relating to the magnetometer constants, and a consideration of the formulæ involved in the reductions. As in the previous paper, the stations are all fully described, and the original records with computations are reproduced. The results from the 16 stations occupied are collected in a subsequent table. Here again Professor Palazzo studies the relation between the inclination and latitude. He finds the curve to be in this case a straight line, instead of slightly parabolic as before. A determination of the position of the magnetic equator, using the formula of Biot-Mollweide, $\tan \phi = \frac{1}{2} \tan i$, and basing on the observations in Eritrea, gives as the mean result $\Psi = 9^\circ\ 12'$ N. $\pm\ 0.'8$.

As the interior of Eritrea is an elevated plateau 2000 meters above sea-level, rising sharply from the sea-coast, the opportunity is taken to investigate the influence of altitude upon the horizontal intensity. Comparing his results obtained on the sea-coast with those found on the

[1] L. PALAZZO: Alcune misure magnetiche eseguite nell' Est-Africa inglesi e nella Somalia italiana (*Ann. dell' Uff. Centr. di Meteor. e Geod.*, vol. XXXII, parte I; Roma, 1912). La carta magnetica del Benadir (N. 17 delle *Monografie e Rapporti Coloniali:* Roma, 1912). Misure magnetiche in Eritrea (*Ann. dell' Uff. Centr. di Meteor. e Geod.*, vol. XXXV, parte I; Roma, 1914). La distribuzione della forza magnetica terrestre nella media Eritrea (*Rendiconti della R. Accademia dei Lincei*, vol. XXIV, ser. 5ª, 1° sem., fasc. 1°; Roma, 1915).

plateau, Professor Palazzo calculates that the change for a rise of 1 km. is $\Delta H = -7.5\gamma$. The theory of Gauss gives, for this part of Eritrea, $\Delta H = -16.4\gamma$. Then follows a synopsis of other magnetic observations in Eritrea, beginning with those of Lefebvre in 1839, and closing with those of the hydrographic vessel "Staffeta" in 1914. From the results of these, values of the secular variation are derived. There is appended a map of the region traversed, with isomagnetic lines; and also a diagram showing secular variation curves.

The fourth paper *(La distribuzione della forza magnetica terrestre nella media Eritrea)* is an abstract of the preceding, with some additions, presented as an address to the *R. Accademia dei Lincei* at its meeting of January 3, 1915.

In these publications Professor Palazzo makes a valuable contribution to our knowledge of terrestrial-magnetic conditions in Africa. It is hoped that he will be able to carry out his purpose of making further and more extended studies in these little-known regions.

W. F. WALLIS.

BAUER, L. A. AND J. A. FLEMING: *Researches of the Department of Terrestrial Magnetism (Vol. II): Land Magnetic Observations, 1911-1913, and Reports on Special Researches.*[1]

The first portion of this publication contains, in continuation of the previous volume of researches (No. 175, vol. I) and in a similar manner, the results of all magnetic observations made on land by the Department of Terrestrial Magnetism from January 1911 to the end of 1913. In the second portion are given reports on some special researches. New magnetic instruments of light and portable types are described, which were designed, constructed, and used by the Department subsequent to the observations reported on in the first volume. These new instruments include two universal-magnetometer designs, viz. a combined magnetometer and dip circle, and a combined magnetometer and earth inductor. The results of the extensive intercomparisons of instruments at Washington, and in all parts of the world, are given in detail for each instrument.

The stations at which magnetic observations were made between 1911-1913 may be summarized as follows: Africa, 207; Asia, 83; Australasia, 284; Europe, 38; North America, 48; South America, 247; islands of the Atlantic Ocean, 16; islands of the Indian Ocean, 14; islands of the Pacific Ocean, 16; Antarctic regions, 30. The total number of stations is thus 978. The table of results (pp. 26-64) gives names of stations, geographic positions, values of the three magnetic elements, dates and local mean times of observations, references to instruments used, and the initials of observers. From about 18 per cent of the

[1] Carnegie Institution of Washington Pub. No. 175, (vol. II), 1915, quarto, 278 pages, 13 plates and 9 text-figures.

results, data for the determination of the secular variation have been obtained.

Extended extracts from the observers' field reports are given on pages 65-128. Following these are sufficiently detailed descriptions of the magnetic stations occupied during the period 1911-1913 (pp. 129-182).

The next section of the volume contains the reports on special researches. The first describes in detail the newly erected research buildings of the Department at Washington, viz. a main fireproof building containing the Director's headquarters, laboratory, and instrument shop; a one-story non-magnetic building to serve as a testing or standardizing magnetic observatory, and several smaller accessory structures for special investigations in atmospheric electricity and allied subjects. The second report is devoted to L. A. Bauer's inspection trip of 1911, in the course of which he visited various magnetic institutions, and to the observations secured at Manua, Samoa, during the total solar eclipse on April 28, 1911. On plate 10 is a full-size reproduction of the photograph obtained of the eclipse, showing the coronal extensions corresponding to a period of minimum sun-spot activity. The concluding report is concerned with the results of the comparisons of magnetic standards obtained by observers of the Department, during 1905 to 1914, both at magnetic observatories and in the field among themselves.

The plates contain illustrations of the research buildings of the Department and of various instruments; also typical views obtained on field expeditions to all parts of the Earth, and finally views of magnetic observatories. J. A. Fleming.

Dunoyer, L.: *World magnetic surveys.*[1]

The author briefly reviews the first elementary theories advanced to explain the distribution of the Earth's magnetism, and then follows with a résumé of the theory of Gauss, at the conclusion of which he points out the necessity of studying the three magnetic elements defining the Earth's field in any one locality, in order to obtain some knowledge of the relative importance of exterior and interior causes of the distribution. The article has three small charts, one of which compares isodynamics computed by the theory of Gauss with the isodynamics as plotted by Sabine from actual observations. Another is a reproduction of the chart of J. C. Ross, which shows the isogonics and isoclinics in the neighborhood of the south pole, and also the voyages of the *Erebus* and *Terror* in these regions. The various expeditions sent out to study the distribution of the Earth's magnetism over the oceans are briefly noted. The author refers, in conclusion, to the perfection and rapidity of the magnetic work of the Department of Terrestrial Magnetism. W. J. Peters.

[1] L'exploration magnétique des mers et les progrès du magnétisme terrestre pendant la première moitié du XIXe siècle. *Revue générale des sciences pures et appliquées*, Paris, v. 23, No. 2, Jan. 30, 1912, pp. 46-59.

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HONGKONG ROYAL OBSERVATORY. Meteorological observations made at the Royal Observatory, Hongkong, in the year 1912. (T. F. Claxton, Director.) Hongkong, Noronha & Co., Govt. Printers, 1913 (ii + 114 with 2 pls.) 35 cm. [Contains results of monthly observations of the magnetic elements during 1912 at the Royal Observatory, Hongkong.]

HONGKONG, ROYAL OBSERVATORY. Report of the Director of the Royal Observatory, Hongkong, for the year 1912. (T. F. Claxton, Director.) Hongkong, Noronha & Co., Govt. Printers, 1913, 12 pp. 24 cm.

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TERRESTRIAL MAGNETISM
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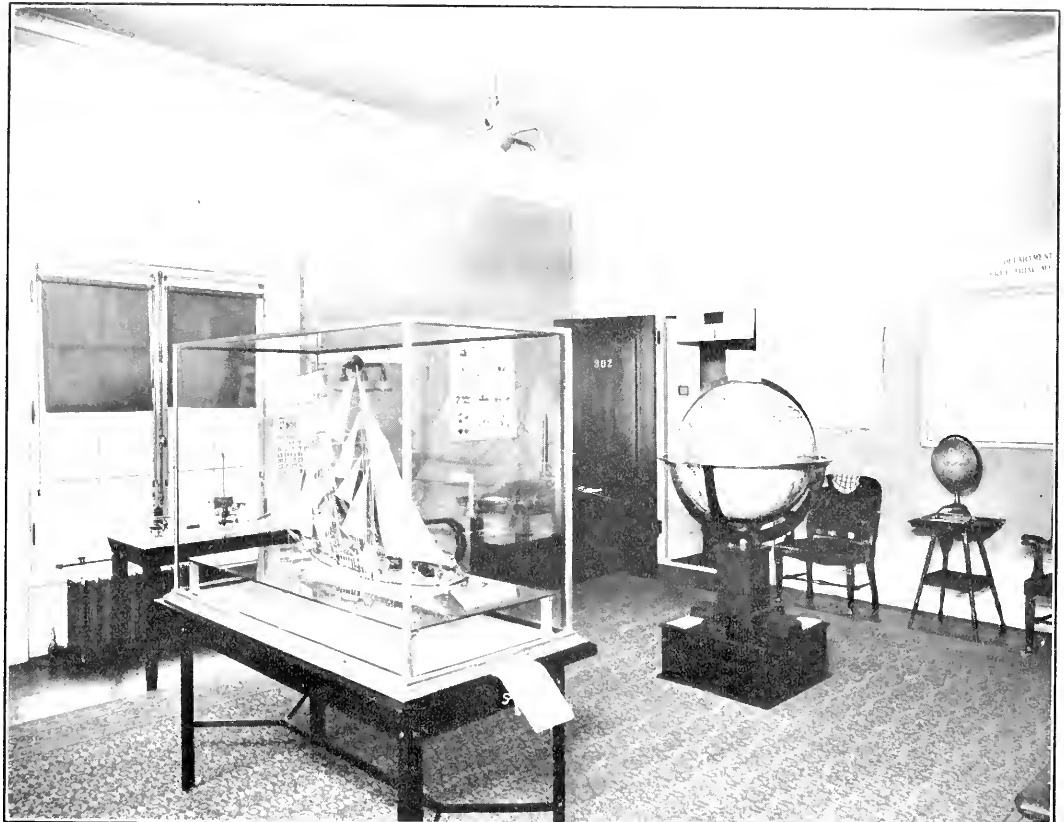

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(Status shown on 30-inch globe.)

EXHIBITS OF DEPARTMENT OF TERRESTRIAL MAGNETISM, AT SAN FRANCISCO, 1915.

Terrestrial Magnetism

and

Atmospheric Electricity

VOLUME XXI — MARCH, 1916 — NUMBER 1

ON THE IONIZATION OF THE UPPER ATMOSPHERE.

BY W. F. G. SWANN.

The subject of the ionization of the upper atmosphere is one of extreme importance to students both of Terrestrial Magnetism and of Atmospheric Electricity, and from various points of view there are indications that this region of the atmosphere is to be treated as one of relatively high electrical conductivity. One of the first theories which took this hypothesis as one of its bases was that developed by Schuster[1] to account for the diurnal variation of the Earth's magnetism.

At the time when Schuster's paper was written the most natural source in which to seek an explanation of the high conductivity was the ultra-violet light from the Sun. The great increase in our knowledge of photo-electric ionization within the last few years renders it now possible to make a closer scrutiny of the consequences to be anticipated from the ultra-violet ionization alone. Any conclusions as to the insufficiency of this source for accounting for such a conductivity as that cited by Schuster must not, of course, be considered in any way as a criticism regarding the broad principles underlying Schuster's work, since the ultra-violet light is by no means the only source of ionization of the atmosphere. Indeed, Schuster himself questioned the sufficiency of this source, and he took pains to point out that other sources were available. Thus, the rate of production of ions in a closed vessel increases at altitudes of 10 kilometers to many times its value at the Earth's surface, and this fact suggests a powerful ionization agent in the upper atmosphere other than the ultra-violet light. In spite of the existence of various agencies which may be invoked to account for the ionization in question, it is not without interest to discuss

[1] *Phil. Trans.*, v. 208, p. 163 (1908).

in terms of modern views as to photo-electric ionization the possibilities inherent in the ultra-violet light alone.

First as regards the fraction of the total solar energy which is available for gaseous ionization. According to the work of Hughes[2], ionization of air by ultra-violet light does not occur for wave-lengths greater than 135 $\mu\mu$. On the basis of the quantum theory, according to which the energy required to ionize a molecule is $h\,\nu$, h being Planck's constant, and ν the frequency corresponding to the wave-length 135 $\mu\mu$, we should calculate for the said energy the amount corresponding to the fall of the ionic charge through 9.2 volts. This value further agrees well with the value 9.0 volts, found by Franck and Hertz[3] from other considerations.

The energy per c.c. contained between the frequencies of values ν_1 and infinity is in the case of black body radiation

$$E_1 = \frac{8\pi}{c^3}\int_{\nu_1}^{\infty}\frac{h\nu^3}{e^{\frac{h\nu}{RT}}-1}\,d\nu = \frac{8\pi R^4 T^4}{c^3\,h^3}\int_{\frac{h\nu_1}{RT}}^{\infty}\frac{x^3}{e^x-1}\,dx$$

where R is the gas constant, T the temperature, and c the velocity of light.

The whole energy E per c.c. of the black body radiation is

$$E = \frac{8\pi}{c^3}\int_0^{\infty}\frac{h}{e^{\frac{h\nu}{RT}}-1}\,d\nu = \frac{48\pi R^4 T^4}{c^3\,h^3}\,\alpha$$

$$\text{where } \alpha = 1 + \frac{1}{2^4} + \frac{1}{3^4} + \frac{1}{4^4} + \cdots\cdots = 1.0823$$

$$\text{Hence } \frac{E_1}{E} = \frac{1}{6\,\alpha}\int_{\frac{h\nu_1}{RT}}^{\infty}\frac{x^3}{e^x-1}\,dx$$

Hence the limits of x are given by $\frac{h\,\nu_1}{R\,T}$ and infinity, where $135\,\nu_1 \times 10^{-7} = c$, since the critical wave-length for ionization is 135×10^{-7} cms.

Now $h = 6.548 \times 10^{-27}$ erg. sec., and $R = 1.346 \times 10^{-16}$ erg. deg.$^{-1}$.

$$\text{Hence } \frac{h\,\nu_1}{RT} = \frac{h\,c}{135\,RT} \times 10^7 = 18.0.$$

[2] HUGHES: *Proc. Camb. Phil. Soc.*, 15, pp. 483-491, 1910; *Phil. Mag.*, 25, p. 685, 1913.

[3] FRANCK AND HERTZ: *Deutsch. Phys. Gesell. Verh.*, 15, p. 34, 1913.

where we have taken 6000 Centigrade degrees absolute as the temperature of the Sun.

Since e^{18} is very large compared with unity, we may write

$$\frac{E_1}{E} = \frac{1}{6\,a}\int_{18}^{\infty} x^3 e^{-x} dx = \frac{1}{6\,a}\Big[(x^3 + 3x^2 + 6x + 6)\,e^{-x}\Big]_{\infty}^{18} \qquad (1)$$

Putting in the value $a = 1.0823$, we obtain

$$\frac{E_1}{E} = 1.61 \times 10^{-5}$$

Thus if we treat the radiation from the Sun as black body radiation (an assumption which cannot, of course, be completely justified), a fraction amounting to only 1.61×10^{-5} of the radiation entering the atmosphere is available for ionization. It must, however, be remarked that if there is in the upper atmosphere any constituent for which the ionization-potential is smaller than 9 volts, the ratio found above would be greater, and, further, a small change in the ionization makes a large change in the ratio $\frac{E_1}{E}$ near the values of ν_1 concerned, on account of the exponential factor in (1). Thus the ionization-potential for nitrogen is 7.5 volts, and for this gas $\frac{E_1}{E}$ is 1.96×10^{-4}. If there is a gas in the upper atmosphere for which the ionization-potential is as low as 4.5 volts, $\frac{E_1}{E}$ would be 3.1×10^{-2}.

It will thus be seen that only a very small portion of the solar radiation is available for direct gaseous ionization, and that a portion in the extreme ultra-violet region of the spectrum, so that it would only be to the extent that variations of radiation-intensities in one portion of the spectrum may be taken as evidence of variations in another portion that measurements of the solar constant, for example, and of its variations serve as a criterion for the variation of the direct influence of solar radiation as an ionizing agency.

Let us now consider the amount of atmospheric-conductivity which is capable of being accounted for by the ultra-violet light. Writing k for the ratio $\frac{E_1}{E}$ for the particular gas concerned, we see that kS represents the energy per second available for ionization in a sunbeam column of cross-section 1 sq. cm. passing through

the Earth's atmosphere. Here S is the solar constant expressed in ergs per sq. cm. per sec., and is equal to 1.35×10^6.

If V is the ionization-potential in volts, and e the electronic charge (4.7×10^{-10} E. S. U.), the energy necessary to produce a pair of ions is

$$\frac{4.7 \times 10^{-10}}{300} V = 1.57 \times 10^{-12} V$$

Hence the rate of production of ions as a result of the complete absorption of the $1.35\,k \times 10^6$ ergs of effective ultra-violet radiation in the sunbeam column above referred to is,

$$\frac{1.35}{1.57}\frac{k}{V} \times 10^{18} = 0.86 \frac{k}{V} \times 10^{18} \text{ ions per second.}$$

In order to discuss the effect of this ionization we shall consider a case of the nature cited by Schuster, [4] viz., one where the ionization is confined to a conducting layer 300 kilometers thick in a region where the average pressure is 1 dyne per sq. cm. If we were to imagine the ionization as spread uniformly throughout the length of the sunbeam column, we should find for q, the rate of production of ions per c.c. in this column, when the Sun was in the zenith.

$$q = 0.86 \frac{k}{V} \times 10^{18} \times 0.33 \times 10^{-7} = 0.29 \frac{k}{V} \times 10^{11} \qquad (2)$$

The relation between the number of ions per c.c. of either kind and q is $q = \alpha n^2$, where α is the coefficient of recombination, so that the conductivity σ, which is $2\,n\,e\,v$, is given by

$$\sigma = 2\,e\,v \sqrt{\frac{q}{\alpha}}$$

Here we have assumed as an approximation equal specific velocities (v) for ions of both signs. Now the value of α at the surface of the Earth is about 3.3×10^{-6}; α decreases with decrease of pressure, as is shown by the following table:

Pressure in cms. Hg. .	76	25	15	5	2	1
$\alpha \times 10^6$.	3.3	2.07	1.75	1.55	1.15	1.00

The value of α increases with decrease in temperature, however, until at liquid-air temperatures it attains a value about double its normal value.

According to the general indications shown by the above

[4] *Phil. Trans.*, v. 208, p. 163 (1908).

table, a would attain a limiting value at low pressures, and we shall probably not be far wrong in taking 10^{-6} for this limiting value. The value of v, at constant temperature, varies inversely as the pressure, so that at an altitude where the pressure is of the order of magnitude of 1 dyne per sq. cm., the specific velocity would be 10^6 times the value at the Earth's surface, i. e., it would amount to about 4×10^8 cm./sec. per E. S. U. per cm. Hence, from (2) and (3) we have for

$$\sigma = 2 \times 4.7 \times 10^{-10} \times 4 \times 10^{8} \times 10^{3} \times 10^{5} \left(\frac{2.9\,k}{V}\right)^{1/2} = 6 \times 10^{7} \left(\frac{k}{V}\right)^{1/2}$$

For the case of oxygen, as we have seen, $k = 1.6 \times 10^{-5}$, and $V = 9$. Hence $\sigma = 8 \times 10^4$ E. S. U. The value of σ required by Schuster's theory is[5] 10^{-13} E. M. U., i. e., 9×10^7 E. S. U.,[6] so that it is about 10^3 times as large as that which could be accounted for on the basis of the above calculation. The rate of production of ions, which is the quantity more directly connected with the ionizing agency, is proportional to the square of σ, thus the value of q necessary to account for a conductivity of 10^{-13} E. M. U. is on the basis of the above calculation about 10^6 times the value which could be obtained by the absorption of the ultra-violet radiation. Indeed, if the whole of the Sun's radiant energy were absorbed in the act of producing ionization, we can readily see, since $k = 1.6 \times 10^{-5}$, that the rate of ionization which could be accounted for would still be only about one-sixteenth of that required. The variations which take place in the latter estimate, as a result of assuming different values for the ionization voltage, do not, of course, affect the order of magnitude of the quantity, since for this case q would only vary inversely as the first power of V.

Any departure from a condition of uniform ionization in the conducting layer would be in the direction of reducing still further the conductivity to be accounted for by the ultra-violet light, for since the rate of recombination is proportional to n^2, it is readily

[5] *Phil. Trans.*, v. 108, p. 139 (1908).

[6] Since $2n = \sigma / ev$, n equals about $10^{17}/v$. Again if v is inversely proportional to the pressure, $v = \frac{v_0 p_0}{p}$, where v_0 and p_0 refer to normal pressure. Hence $n = \frac{10^{17} p}{v_0 p_0}$. If N is the number of molecules per c.c. at the pressure p, and at 0°C $N = 2.75 \times 10^{19} \frac{p}{p_0}$, and since v_0 about 400, $\frac{n}{N} = \frac{1 \times 10^{-2}}{2.75 \times 300}$ = about 8×10^{-6}.

The interesting point which results from this calculation is that $\frac{n}{N}$, which represents the ratio of the number of pairs of ions to the number of molecules available for ionization, is independent of the pressure for a constant value of the conductivity.

seen that a given number of pairs of ions will combine less rapidly when they are distributed uniformly than when distributed non-uniformly throughout a given volume.

It must be remarked that if the product of the thickness of the layer into the conductivity is to be maintained constant, a smaller amount of ultra-violet radiation is necessary for thick layers than for thin ones, for, if l is the thickness of the layer, and Q is the amount of ultra-violet radiation energy falling on 1 sq. cm. of it, we have $\frac{Q}{l} = \alpha\, n^2$. Hence $Q\, l = \alpha\, n^2\, l^2$. If $n\, l$ is to be constant, Q must be constant, so that the amount of radiation necessary to account for a given value of the product of conductivity and thickness of layer is proportional to l^{-1}. It will be obvious, therefore, that but little can be done in altering the order of magnitude of the numbers in the above discussion, by an appeal to the effect of increasing the thickness of the layer. A more powerful loophole out of the difficulty might appear to be found in the assumption of a smaller pressure in the layer; this would result in a large specific ionic velocity. The above calculations have been based on a pressure of 1 dyne per sq. cm., and since the conductivity is inversely proportional to this quantity for a given intensity of ionization, the total ultra-violet energy necessary is inversely proportional to its square.

A very curious circumstance results from a closer scrutiny of the phenomenon along these lines. As will be seen from the following calculation, the conductivity of the atmosphere should theoretically tend to an infinite value with increase of altitude if we make the assumptions as to the variation of the various quantities with pressure, applicable at pressures which are measurable.

Thus, let I be the amount of ultra-violet energy falling on 1 sq. cm. of a sphere surrounding the Earth when the Sun is at the zenith, and let us measure x vertically downwards from some point at a very high altitude. Let N be the number of gas molecules per c.c., so that

$$-\frac{dI}{dx} = \beta\, N\, I \tag{4}$$

where β is a constant.

If ϵ is the energy required to produce an ion, we have, $q = -\epsilon \frac{dI}{dx}$.

Hence $\alpha\, n^2 = \epsilon\, \beta\, N\, I$ and $\alpha^2\, \sigma^2 = \alpha^2\, n^2\, e^2\, v^2 = \alpha\, \epsilon\, \beta\, e^2\, v^2\, N\, I$.

Now if u is the square root of the mean square velocity of a

gas molecule, and λ the mean free path, we should expect v to vary as $\frac{\lambda}{u}$, i. e., as $\frac{1}{N u}$. Hence $v^2 N$ varies as $\frac{1}{N u^2}$, and hence as the reciprocal of the pressure.

Thus, $\alpha^2 \sigma^2 = \alpha \epsilon \beta e^2 v_0^2 N_0 I \frac{p_0}{p}$

where the quantities with subscript zero refer to the standard pressure p_0. From (4) $I = I_0 e^{-\beta \int N dx}$, where I_0 refers to the point at great altitude, and since $\int_0^x N\,dx$ is the number of molecules above 1 sq. cm. at the point x, we have

$$I = I_0 e^{-\frac{\beta M}{m}}$$

where M is the mass of gas above 1 sq. cm. situated at the point x. Thus, since $p = M g$, we have from the above

$$\alpha^2 \sigma^2 = \frac{\alpha \epsilon \beta e^2 N_0 v_0^2 I_0 p_0 e^{-\frac{\beta M}{m}}}{g M}$$

and
$$\sigma = K \frac{e^{-\frac{\beta M}{2m}}}{M^{1/2}}$$

$$\text{where } K^2 = \frac{\epsilon \beta e^2 N_0 v_0^2 I_0 p_0}{\alpha g}$$

Now the quantity which is primarily involved in a calculation of the type made by Schuster is the value of $\int \sigma\, d x$ taken across the conducting layer. Calling this integral Q, we have

$$Q = K \int_0^{\bar{x}} \frac{e^{-\frac{\beta M}{2m}}}{M} \frac{dx}{dM} d M$$

where $\bar{x}$ corresponds to a point so low in the atmosphere that the conduction of electricity by the regions below that point may be left out of consideration. Now $\frac{dM}{dx} = m g N$, and since $p = \frac{2}{3} N R T$, where R is the gas constant and T the absolute temperature, we have since $p = M g$,

$$\frac{dM}{dx} = \frac{3 m g^2 M}{2 RT}$$

$$\text{Hence} \quad Q = \frac{2}{3}\frac{RK}{mg^2}\int_0^{\bar{M}} \frac{T^{\frac{1}{2}}\, e^{-\frac{\beta M}{2m}}}{M^{\frac{3}{2}}}\, dM \qquad (5)$$

where M is the amount of gas contained above 1 sq. cm. at the point $\bar{x}$.

Now unless T tends to zero as M tends to zero this integral is infinite for finite values of $\bar{M}$. The infinite value arises from the very large contributions to the integral as M becomes small, and the physical representation of this circumstance is, of course, the increase of specific velocity with the altitude, which so powerfully influences the phenomenon that very large values of Q may arise even for small amounts of ionizations. Of course, in integrating from $M = 0$ we are theoretically integrating from a point at an infinite altitude and so should take into account the spherical shape of the Earth. This is not a circumstance which has more than a formal significance in the problem, however, as the above calculation is only intended to illustrate the nature of the effect.

Probably the quantity in (5) concerning which we know least is β, which occurs in the exponential and also in the factor K; β is proportional to the coefficient of absorption of the ultra-violet light concerned, for the gases of the upper atmosphere. The importance of β in the exponential term is not so great in the regions which contribute most to the effect since here the exponential term is practically unity, but $\beta^{1/2}$ occurs as a factor in K and without knowledge of it we cannot estimate how much of Q would be contributed by the air below any assigned altitude. It will readily be seen from various considerations that it is only provided that a good slice, so to speak, of the infinite value of Q predicated by the formula (5) is to be accounted for by the air within a reasonable distance from the Earth, the calculation can be said to have much meaning; (5) is perhaps not without interest, however, in indicating some of the salient features involved.

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RESULTS OF MAGNETIC OBSERVATIONS MADE BY THE UNITED STATES COAST AND GEODETIC SURVEY AT THE TIME OF THE SOLAR ECLIPSE OF AUGUST 21, 1914.

By D. L. Hazard.

In response to a request from Dr. L. A. Bauer for additional data for the study of the effect of an eclipse of the Sun upon the Earth's magnetism, the following results have been derived from the records of the five magnetic observatories of the Coast and Geodetic Survey.

At each of the observatories, except Porto Rico, eye-readings of declination were made once a minute from 10 to 15 o'clock Greenwich mean civil time on August 21, 1914. The results of these observations are not published here, however, as they are essentially the same as the magnetograph values.

Care was taken to have the variation instruments in good working order on the day of the eclipse. All of the observatories are supplied with magnetographs of the Eschenhagen type with a time scale of 20 mm. to the hour. The values of declination (*D*), horizontal intensity (*H*), and vertical intensity (*Z*) have been derived from the magnetograms for every five minutes for the specified period. The change in temperature in the instrument room during the five hours in no case amounted to more than 0.°1 Centigrade. In reading the ordinates from the magnetograms a graphical integration was attempted, so that a tabular result is approximately the average value for the 5-minute period of which the tabular time is in the middle.

The location of the observatories and necessary data regarding the variometers are as follows:

Table 1. *Location of the magnetic observatories.*

Station	State	Latitude ° ′	Longitude ° ′	Observer-in-Charge
Vieques,	Porto Rico	18 08.8N	65 26.9W	H. W. Pease
Cheltenham,	Maryland	38 44.0N	76 50.5W	G. Hartnell
Tucson,	Arizona	32 14.8N	110 50.1W	F. Neumann
Sitka,	Alaska	57 03.0N	135 20.1W	J. W. Green
Honolulu,	Hawaii	21 19.2N	158 03.8W	Wm. W. Merrymon

TABLE 2. *Magnetic elements and scale values for August,* 1914.

Observatory	Magnetic Elements Mean of 10 selected days			Scale Values of the Magnetograph		
	D	H	Z	D	H	Z
	° ′	γ	γ	′	γ	γ
Porto Rico,	3 01.7W	28388	34541(N)	1.02	2.63	6.42
Cheltenham,	6 00.5W	19493	55788(N)	1.00	2.33	4.84
Tucson,	13 40.1 E	27177	45938(N)	1.00	2.23	2.98
Sitka,	30 23.6 E	15599	56034(N)	1.03	4.39	5.61
Honolulu,	9 39.9 E	29038	23946(N)	1.02	2.28	2.77

The following tables show the average diurnal variation of *D*, *H*, and *Z* for ten selected quiet days in August, 1914. A + sign means a motion of north end of the magnet toward the east for *D*; for *H* and *Z* it means that the values of these elements were greater at the time than the mean values for the day.

TABLE 3. *Diurnal variation of declination, August, 1914.*

L. M. T.	Porto Rico	Cheltenham	Tucson	Sitka	Honolulu
h	′	′	′	′	′
1	0.0	+0.3	+0.3	−1.6	−0.3
2	−0.1	+0.4	+0.2	−2.2	−0.2
3	0.0	+0.1	−0.1	−1.2	−0.1
4	+0.1	+0.6	0.0	−0.2	+0.2
5	+0.5	+1.8	+0.9	+1.7	+0.5
6	+1.3	+3.3	+2.1	+3.7	+1.7
7	+2.9	+5.1	+3.9	+6.5	+4.1
8	+3.3	+5.7	+5.1	+7.9	+4.5
9	+2.4	+4.4	+3.7	+7.8	+3.4
10	+1.0	+1.0	+0.9	+5.3	+0.9
11	0.0	−2.6	−1.9	+1.5	−1.2
12	−0.8	−5.1	−3.5	−2.1	−2.8
13	−1.7	−6.0	−4.0	−3.8	−3.3
14	−2.4	−5.5	−3.4	−5.2	−2.6
15	−2.5	−4.1	−2.4	−5.2	−1.8
16	−2.0	−2.4	−1.2	−4.7	−1.0
17	−0.8	−1.0	−0.5	−3.2	−0.5
18	−0.5	+0.6	−0.2	−1.6	−0.3
19	−0.3	+0.4	−0.3	−1.3	−0.3
20	−0.3	+0.4	0.0	−1.2	−0.1
21	−0.1	+0.8	+0.1	+0.2	−0.1
22	0.0	+0.6	+0.1	−0.6	−0.2
23	+0.1	+0.7	+0.3	−0.4	−0.3
24	+0.1	+0.5	−0.1	−0.3	−0.3

TABLE 4. *Diurnal variation of horizontal intensity, August, 1914.*

L. M. T.	Porto Rico	Cheltenham	Tucson	Sitka	Honolulu
h	γ	γ	γ	γ	γ
1	− 1	+ 8	+ 4	+10	− 1
2	0	+ 5	+ 2	+11	− 2
3	− 1	+ 5	+ 4	+11	− 1
4	0	+ 3	+ 4	+10	0
5	− 2	+ 1	+ 3	+10	0
6	0	0	+ 4	+14	+ 1
7	− 2	− 2	− 1	+18	+ 2
8	− 1	−14	− 9	+11	+ 2
9	+ 2	−28	− 8	0	+ 3
10	+ 8	−32	− 5	−17	+ 5
11	+12	−22	− 2	−30	+ 5
12	+12	− 8	+ 3	−31	+ 5
13	+ 9	+ 6	+ 6	−28	+ 4
14	+ 4	+14	+ 3	−19	+ 2
15	− 1	+16	− 1	−15	+ 1
16	− 6	+13	− 4	+ 1	0
17	− 8	+ 7	− 5	+ 3	− 2
18	− 6	+ 4	− 4	+ 5	− 3
19	− 3	+ 4	− 1	+ 7	− 3
20	− 3	+ 3	− 1	+ 5	− 4
21	− 4	+ 4	0	+ 4	− 4
22	− 3	+ 5	0	+ 6	− 4
23	− 2	+ 4	+ 3	+ 6	− 3
24	− 2	+ 5	+ 4	+ 8	− 3

TABLE 5. *Diurnal variation of vertical intensity, August, 1914.*

L. M. T.	Porto Rico	Cheltenham	Tucson	Sitka	Honolulu
h	γ	γ	γ	γ	γ
1	+ 1	0	+ 3	0	+ 3
2	+ 2	− 1	+ 3	− 4	+ 4
3	+ 1	− 1	+ 4	− 5	+ 4
4	0	0	+ 4	− 3	+ 5
5	− 1	+ 3	+ 5	− 3	+ 4
6	0	+ 4	+ 8	− 2	+ 9
7	− 5	+ 4	+ 9	− 3	+15
8	− 8	+ 2	+ 5	− 4	+10
9	− 6	− 1	− 4	− 6	0
10	− 4	− 8	−11	− 9	−10
11	− 1	−10	−12	− 8	−16
12	0	−12	−13	− 6	−17
13	+ 1	− 9	−14	− 3	−12
14	+ 3	− 3	− 9	+ 2	− 6
15	+ 3	+ 2	− 3	+ 5	− 3
16	+ 1	+ 6	+ 2	+ 8	− 1
17	+ 1	+ 6	+ 4	+10	0
18	0	+ 5	+ 4	+ 8	− 1
19	+ 1	+ 3	+ 2	+ 7	0
20	+ 2	+ 3	+ 3	+ 7	+ 2
21	+ 1	+ 3	+ 3	+ 5	+ 2
22	+ 2	+ 2	+ 3	+ 3	+ 2
23	+ 3	+ 1	+ 3	+ 1	+ 2
24	+ 3	0	+ 3	− 1	+ 3

Table 6. *Magnetograph values of declination on August 21, 1914.*

G. M. T.	Porto Rico	Cheltenham	Tucson	Sitka	Honolulu
h m	° '	° '	° '	° '	° '
10 00	3 01.2W	5 60.3W	13 39.5 E	30 22.6 E	9 39.7 E
05	01.3	61.0	38.6	20.6	39.7
10	01.2	61.1	38.0	17.1	39.7
15	01.1	61.2	37.9	18.1	39.6
20	00.9	61.2	38.0	19.8	39.5
25	00.9	60.9	38.3	20.2	39.4
30	00.6	60.4	38.7	19.0	39.3
35	00.4	60.2	38.7	17.8	39.3
40	00.2	60.2	38.7	17.0	39.3
45	2 59.9	5 59.9	38.6	17.0	39.2
50	59.8	59.6	38.7	17.0	39.2
55	59.4	59.0	38.8	19.3	39.3
11 00	59.2	58.7	39.1	21.3	39.5
05	59.1	58.3	39.4	22.2	39.4
10	58.9	58.0	39.5	22.1	39.5
15	58.9	57.9	39.9	22.5	39.6
20	58.8	57.9	40.0	23.2	39.6
25	58.6	57.6	40.0	23.0	39.5
30	58.4	57.3	40.0	21.9	39.5
35	58.3	57.0	40.1	21.2	39.6
40	58.2	56.8	40.2	21.6	39.3
45	58.0	56.4	40.2	21.6	39.3
50	58.1	56.1	40.3	21.9	39.2
55	58.0	56.1	40.3	21.5	39.3
12 00	58.2	56.0	40.4	22.3	39.3
05	58.3	56.0	40.6	22.2	39.2
10	58.4	55.9	40.6	21.9	39.2
15	58.3	55.3	40.7	22.0	39.3
20	58.3	55.0	40.9	22.6	39.5
25	58.4	55.0	41.1	23.3	39.6
30	58.4	55.2	41.3	23.6	39.7
35	58.5	55.3	41.3	23.2	39.7
40	58.6	55.1	41.3	22.6	39.5
45	58.8	56.0	41.2	20.6	39.3
50	58.9	56.0	40.9	18.9	39.0
55	59.1	56.1	40.7	17.4	39.0
13 00	59.3	56.0	40.8	15.7	39.0
05	59.5	56.1	40.9	15.7	39.1
10	59.7	56.1	41.0	16.6	39.2
15	59.8	56.4	41.2	17.1	39.4
20	59.9	56.8	41.3	17.8	39.5
25	3 00.1	57.0	41.5	18.8	39.6
30	00.4	57.4	41.6	19.5	39.6
35	00.5	57.5	41.8	20.2	39.6
40	00.7	57.9	42.0	20.4	39.6
45	00.8	58.0	42.3	19.5	39.6
50	00.9	58.1	42.6	20.8	39.6
55	01.1	58.6	42.6	21.6	39.7
14 00	01.2	58.9	42.9	23.0	39.8
05	01.4	59.4	43.2	23.9	39.8
10	01.7	59.9	43.3	24.5	39.9
15	01.8	60.0	43.6	26.1	40.0
20	01.9	60.2	43.9	27.4	40.1
25	02.1	60.6	44.1	27.5	40.1
30	02.2	60.7	44.3	27.9	40.2
35	02.4	61.0	44.7	28.4	40.3
40	02.4	61.0	44.8	28.9	40.4
45	02.5	61.0	45.0	29.0	40.4
50	02.6	61.0	45.5	29.4	40.5
55	02.7	61.3	45.7	30.3	40.5
15 00	02.8	61.6	45.7	30.1	40.5

TABLE 7. *Magnetograph values of horizontal intensity on August 21, 1914.*

G. M. T. h m	Porto Rico γ	Cheltenham γ	Tucson γ	Sitka γ	Honolulu γ
10 00	28378	19489	27177	15605	29032
05	378	487	182	623	036
10	378	487	184	608	037
15	378	489	183	597	037
20	378	490	183	592	036
25	378	491	182	591	036
30	378	489	180	592	036
35	377	491	180	596	037
40	377	490	180	596	039
45	377	491	180	596	039
50	377	491	180	596	039
55	377	494	180	596	038
11 00	377	495	180	602	036
05	377	494	179	605	036
10	377	494	178	608	035
15	377	496	178	610	035
20	377	496	178	613	035
25	377	496	178	614	035
30	377	495	178	612	035
35	376	495	177	609	035
40	376	496	177	610	035
45	376	495	176	609	034
50	377	496	177	609	034
55	377	495	177	608	034
12 00	378	495	177	608	034
05	378	494	176	607	033
10	379	494	176	605	034
15	380	492	176	605	032
20	380	491	175	605	032
25	380	490	174	602	031
30	381	488	174	601	031
35	382	486	174	600	031
40	382	482	174	598	032
45	383	480	174	591	033
50	384	478	173	583	035
55	385	477	173	578	036
13 00	386	476	173	579	036
05	387	474	173	583	036
10	387	471	173	589	036
15	388	468	173	591	036
20	388	468	173	592	036
25	389	466	174	595	036
30	390	465	175	597	036
35	390	463	175	597	036
40	391	461	174	596	036
45	392	458	173	597	036
50	393	458	173	597	036
55	394	455	173	596	037
14 00	395	454	173	597	036
05	396	453	173	598	035
10	396	452	171	600	035
15	397	451	170	601	034
20	398	448	169	605	033
25	399	447	167	605	033
30	401	447	165	604	032
35	401	447	163	605	032
40	401	447	162	607	031
45	401	447	160	605	031
50	402	446	157	605	030
55	402	448	157	608	030
15 00	402	447	155	609	030

TABLE 8. *Magnetograph values of vertical intensity on August 21, 1914.*

G. M. T.	Porto Rico	Cheltenham	Tucson	Sitka	Honolulu
h m	γ	γ	γ	γ	γ
10 00	34547	55772	45940	56025	23951
05	547	772	940	022	951
10	547	773	939	013	951
15	546	773	939	003	950
20	545	773	939	55998	949
25	545	774	939	996	950
30	544	774	939	999	950
35	543	774	939	56001	950
40	543	774	939	000	950
45	542	774	939	55999	950
50	542	774	939	997	949
55	541	776	939	996	949
11 00	540	776	939	997	949
05	540	776	939	56000	949
10	539	776	939	006	949
15	538	777	939	009	949
20	538	777	939	011	950
25	538	777	939	015	950
30	536	777	939	017	949
35	536	777	939	021	949
40	536	779	939	022	949
45	535	778	939	023	949
50	536	779	939	024	949
55	536	778	940	025	949
12 00	537	778	940	025	949
05	537	778	940	027	949
10	537	778	940	027	949
15	537	778	940	028	949
20	538	779	940	027	949
25	538	778	940	027	950
30	538	778	941	027	950
35	537	778	941	027	950
40	537	778	942	027	950
45	538	777	942	027	950
50	538	778	942	027	950
55	538	777	942	027	950
13 00	538	777	942	027	949
05	539	777	943	022	950
10	538	776	943	016	950
15	538	776	944	011	950
20	538	776	945	009	950
25	539	776	945	007	950
30	540	776	945	006	950
35	540	775	946	007	950
40	540	773	947	007	950
45	540	772	947	010	950
50	541	772	948	008	950
55	541	771	948	007	950
14 00	542	770	948	005	950
05	543	769	949	005	950
10	543	768	949	004	951
15	543	768	949	004	951
20	543	767	949	004	952
25	543	767	950	005	952
30	543	766	950	008	952
35	543	766	950	009	952
40	543	764	950	010	952
45	542	762	950	012	952
50	542	762	949	014	952
55	542	761	949	016	952
15 00	542	758	948	017	952

DIVISION OF TERRESTRIAL MAGNETISM,
U. S. COAST AND GEODETIC SURVEY,
Washington, D. C.

MAGNETIC DECLINATIONS AND CHART CORRECTIONS OBTAINED BY THE *CARNEGIE* FROM DUTCH HARBOR, ALASKA, TO LYTTELTON, NEW ZEALAND, AUGUST-NOVEMBER, 1915.[1]

By J. P. Ault, Commanding the *Carnegie*.

(*Observers:* J. P. Ault, H. M. W. Edmonds, I. A. Luke, H. F. Johnston, and H. E. Sawyer. *Minus sign indicates west declination, and plus, east declination*).

Date	Position Latitude	Position Longitude	Carnegie	Chart Values Brit.[2]	Chart Values Ger.[3]	Chart Values U. S.[4]	Chart Corrections Brit.	Chart Corrections Ger.	Chart Corrections U. S.
1915	° ′	° ′	°	°	°	°	°	°	°
Aug. 7	57 37N	166 58W	+16.4	+16.8	+16.9	+16.7	−0.4	−0.5	−0.3
8	58 07N	166 48W	+16.4	+17.0	+17.1	+16.8	−0.6	−0.7	−0.4
8	57 55N	168 22W	+15.1	+16.2	+16.0	+16.0	−1.1	−0.9	−0.9
8	57 53N	168 34W	+14.7	+16.0	+15.9	+15.9	−1.3	−1.2	−1.2
9	57 40N	169 01W	+15.4	+15.8	+15.6	+15.6	−0.4	−0.2	−0.2
10	59 05N	171 29W	+15.4	+14.7	+14.9	+14.4	+0.7	+0.5	+1.0
10	59 01N	172 24W	+13.5	+14.1	+14.4	+13.8	−0.6	−0.9	−0.3
11	59 26N	172 40W	+12.5	+14.0	+14.3	+13.8	−1.5	−1.8	−1.3
11	59 29N	174 00W	+11.4	+13.2	+13.6	+13.0	−1.8	−2.2	−1.6
12	59 01N	176 17W	+11.6	+11.7	+11.7	+11.4	−0.1	−0.1	+0.2
12	58 36N	177 39W	+ 9.4	+10.8	+10.9	+10.4	−1.4	−1.5	−1.0
12	58 30N	177 58W	+10.2	+10.6	+10.6	+10.1	−0.4	−0.4	+0.1
13	57 49N	179 42W	+ 9.2	+ 9.4	+ 9.2	+ 9.1	−0.2	0.0	+0.1
13	56 57N	178 36 E	+ 7.6	+ 8.2	+ 8.1	+ 8.2	−0.6	−0.5	−0.6
15	56 44N	177 05 E	+ 6.7	+ 7.4	+ 6.9	+ 7.4	−0.7	−0.2	−0.7
15	56 28N	177 02 E	+ 6.9	+ 7.3	+ 6.8	+ 7.3	−0.4	+0.1	−0.4
16	55 49N	175 37 E	+ 6.1	+ 6.4	+ 6.2	+ 6.5	−0.3	−0.1	−0.4
16	55 28N	174 01 E	+ 4.8	+ 5.5	+ 5.1	+ 5.4	−0.7	−0.3	−0.6
17	54 35N	173 21 E	+ 4.7	+ 5.1	+ 4.8	+ 5.0	−0.4	−0.1	−0.3
17	53 35N	171 55 E	+ 3.7	+ 4.2	+ 4.0	+ 4.1	−0.5	−0.3	−0.4
18	52 22N	170 18 E	+ 3.3	+ 3.4	+ 3.3	+ 3.4	−0.1	0.0	−0.1
19	51 13N	168 38 E	+ 2.2	+ 2.6	+ 2.6	+ 2.6	−0.4	−0.4	−0.4
20	49 46N	168 16 E	+ 1.9	+ 2.4	+ 2.5	+ 2.5	−0.5	−0.6	−0.6
21	48 14N	168 22 E	+ 1.7	+ 2.7	+ 2.6	+ 2.7	−1.0	−0.9	−1.0
21	48 04N	167 43 E	+ 2.1	+ 2.3	+ 2.4	+ 2.4	−0.2	−0.3	−0.3
22	47 27N	166 45 E	+ 1.7	+ 1.8	+ 2.0	+ 2.0	−0.1	−0.3	−0.3
22	46 39N	165 52 E	+ 1.2	+ 1.5	+ 1.8	+ 1.7	−0.3	−0.6	−0.5
23	45 48N	164 43 E	+ 0.8	+ 1.0	+ 1.5	+ 1.4	−0.2	−0.7	−0.6
23	45 20N	164 00 E	+ 0.7	+ 0.8	+ 1.2	+ 1.1	−0.1	−0.5	−0.4
24	45 00N	163 18 E	+ 0.7	+ 0.5	+ 1.0	+ 0.9	+0.2	−0.3	−0.2
24	44 38N	162 48 E	+ 0.3	+ 0.5	+ 1.0	+ 0.7	−0.2	−0.7	−0.4
25	44 32N	162 49 E	+ 0.2	+ 0.5	+ 1.0	+ 0.7	−0.3	−0.8	−0.5

[1] For previous tables, see *Terr. Mag.*, v. 15, pp. 57-82, 129-144; v. 16, pp. 133-136; v. 17, pp. 31-32, 97-101, 141-144, 179-180; v. 18, pp. 63-64, 111-112, 161-162; v. 19, pp. 38, 126, 204, 234-235; v. 20, pp. 69-70, 104.

[2] From British Admiralty Chart No. 2598 for 1912, referred to 1915.

[3] From Reichs-Marine-Amt Chart Tit. XIV, No. 2, for 1910, referred to 1915 by means of the secular change given on the U. S. Chart.

[4] From U. S. Hydrographic Office Chart No. 2406 for 1915.

Date	Position		Carnegie	Chart Values			Chart Corrections		
	Latitude	Longitude		Brit.[2]	Ger.[3]	U. S.[4]	Brit.	Ger.	U. S.
1915	° ′	° ′	°	°	°	°	°	°	°
Aug. 25	44 21N	163 10 E	+0.4	+0.7	+1.0	+1.0	−0.3	−0.6	−0.6
26	40 33N	163 35 E	+1.2	+1.9	+1.8	+1.7	−0.7	−0.6	−0.5
27	39 31N	163 49 E	+1.8	+2.1	+2.3	+2.0	−0.3	−0.5	−0.2
27	38 15N	164 13 E	+2.2	+2.8	+2.8	+2.3	−0.6	−0.6	−0.1
27	37 50N	164 16 E	+2.1	+2.9	+3.0	+2.4	−0.8	−0.9	−0.3
28	36 51N	164 28 E	+2.4	+3.1	+3.2	+2.7	−0.7	−0.8	−0.3
28	36 08N	165 25 E	+3.1	+3.7	+3.7	+3.3	−0.6	−0.6	−0.2
29	35 13N	166 42 E	+4.0	+4.4	+4.4	+4.1	−0.4	−0.4	−0.1
29	34 54N	168 07 E	+4.2	+5.0	+5.1	+4.9	−0.8	−0.9	−0.7
30	34 26N	169 44 E	+5.5	+5.8	+5.8	+5.6	−0.3	−0.3	−0.1
30	33 22N	170 30 E	+5.6	+6.3	+6.2	+6.0	−0.7	−0.6	−0.4
31	32 16N	170 48 E	+6.1	+6.5	+6.6	+6.3	−0.4	−0.5	−0.2
31	31 13N	171 10 E	+6.3	+6.9	+6.8	+6.6	−0.6	−0.5	−0.3
Sept. 1	30 28N	171 18 E	+6.8	+7.1	+7.0	+6.7	−0.3	−0.2	+0.1
1	30 02N	171 06 E	+6.9	+7.1	+7.0	+6.8	−0.2	−0.1	+0.1
2	29 18N	170 42 E	+6.6	+7.1	+6.9	+6.7	−0.5	−0.3	−0.1
2	28 57N	170 35 E	+6.4	+7.1	+6.9	+6.7	−0.7	−0.5	−0.3
3	28 39N	170 16 E	+6.8	+7.0	+6.8	+6.6	−0.2	0.0	+0.2
3	27 59N	170 04 E	+6.4	+7.1	+6.8	+6.6	−0.7	−0.4	−0.2
3	27 41N	170 01 E	+6.6	+7.2	+6.9	+6.6	−0.6	−0.3	0.0
4	27 17N	169 49 E	+6.6	+7.2	+6.8	+6.6	−0.6	−0.2	0.0
4	26 44N	169 23 E	+6.4	+7.0	+6.8	+6.6	−0.6	−0.4	−0.2
4	25 37N	168 35 E	+6.4	+7.0	+6.7	+6.5	−0.6	−0.3	−0.1
5	23 19N	167 30 E	+6.5	+7.0	+6.7	+6.5	−0.5	−0.2	0.0
5	21 56N	167 02 E	+6.3	+7.1	+6.8	+6.6	−0.8	−0.5	−0.3
7	21 27N	169 07 E	+6.8	+7.7	+7.4	+7.2	−0.9	−0.6	−0.4
7	21 31N	169 22 E	+7.0	+7.8	+7.5	+7.3	−0.8	−0.5	−0.3
8	21 21N	169 47 E	+7.4	+7.9	+7.6	+7.4	−0.5	−0.2	0.0
9	21 02N	168 32 E	+7.1	+7.5	+7.2	+7.1	−0.4	−0.1	0.0
10	20 40N	168 13 E	+7.0	+7.4	+7.2	+7.1	−0.4	−0.2	−0.1
10	20 37N	168 04 E	+6.9	+7.4	+7.2	+7.1	−0.5	−0.3	−0.2
11	20 18N	167 41 E	+7.0	+7.4	+7.1	+7.0	−0.4	−0.1	0.0
11	19 44N	166 55 E	+6.6	+7.3	+7.0	+6.9	−0.7	−0.4	−0.3
12	19 14N	166 28 E	+7.0	+7.2	+6.9	+6.9	−0.2	+0.1	+0.1
12	18 36N	166 06 E	+6.6	+7.2	+6.9	+6.8	−0.6	−0.3	−0.2
13	17 32N	165 33 E	+6.6	+7.2	+7.1	+6.8	−0.6	−0.5	−0.2
13	16 34N	165 21 E	+7.1	+7.3	+7.1	+6.9	−0.2	0.0	+0.2
14	15 29N	165 17 E	+6.7	+7.4	+7.2	+7.0	−0.7	−0.5	−0.3
14	14 33N	165 11 E	+6.6	+7.4	+7.2	+7.0	−0.8	−0.6	−0.4
15	14 13N	164 50 E	+6.9	+7.3	+7.2	+7.0	−0.4	−0.3	−0.1
15	14 16N	165 01 E	+6.7	+7.4	+7.2	+7.0	−0.7	−0.5	−0.3
16	14 00N	165 33 E	+6.9	+7.5	+7.4	+7.2	−0.6	−0.5	−0.3
16	13 47N	166 16 E	+7.2	+7.6	+7.6	+7.3	−0.4	−0.4	−0.1
17	13 46N	166 24 E	+7.1	+7.7	+7.7	+7.4	−0.6	−0.6	−0.3
17	13 21N	165 58 E	+7.0	+7.6	+7.5	+7.3	−0.6	−0.5	−0.3
18	12 29N	165 01 E	+7.2	+7.5	+7.4	+7.2	−0.3	−0.2	0.0
18	11 57N	164 32 E	+6.1[5]	+7.4	+7.3	+7.1	−1.3	−1.2	−1.0
19	11 31N	164 23 E	+7.1	+7.4	+7.3	+7.2	−0.3	−0.2	−0.1
19	11 13N	164 12 E	+6.8	+7.4	+7.3	+7.2	−0.6	−0.5	−0.4
20	10 40N	164 06 E	+7.0	+7.4	+7.3	+7.2	−0.4	−0.3	−0.2
20	9 46N	163 56 E	+6.8	+7.4	+7.3	+7.2	−0.6	−0.5	−0.4

[5] Local disturbance; near Marshall Island Atoll.

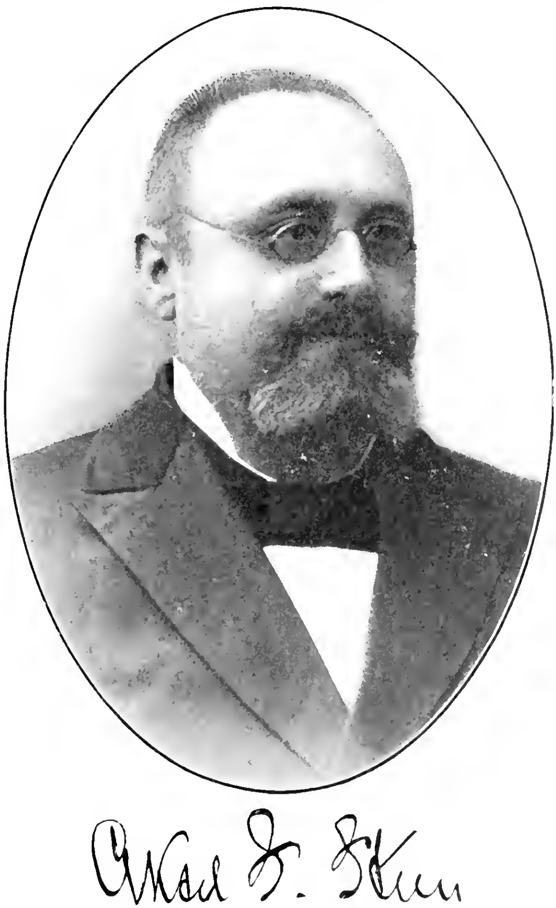
Date	Position		Carnegie	Chart Values			Chart Corrections		
	Latitude	Longitude		Brit.[2]	Ger.[3]	U. S.[4]	Brit.	Ger.	U. S.
1915	° ′	° ′	°	°	°	°	°	°	°
Sept. 21	9 17N	163 41 E	+7.0	+7.4	+7.3	+7.2	−0.4	−0.3	−0.2
21	8 40N	163 29 E	+6.8	+7.4	+7.3	+7.3	−0.6	−0.5	−0.5
22	8 06N	163 32 E	+7.1	+7.4	+7.3	+7.4	−0.3	−0.2	−0.3
22	7 45N	163 47 E	+6.8	+7.5	+7.5	+7.5	−0.7	−0.7	−0.7
23	7 19N	164 05 E	+7.2	+7.6	+7.6	+7.5	−0.4	−0.4	−0.3
23	6 42N	164 20 E	+7.2	+7.7	+7.8	+7.6	−0.5	−0.6	−0.4
24	5 56N	164 38 E	+7.6	+7.7	+7.9	+7.8	−0.1	−0.3	−0.2
24	4 56N	164 33 E	+7.6	+7.8	+8.0	+7.8	−0.2	−0.4	−0.2
25	4 23N	164 14 E	+7.4	+7.8	+7.9	+7.8	−0.4	−0.5	−0.4
25	4 16N	163 54 E	+7.2	+7.8	+7.9	+7.8	−0.6	−0.7	−0.6
26	4 04N	163 50 E	+7.4	+7.8	+7.9	+7.8	−0.4	−0.5	−0.4
27	3 40N	163 56 E	+7.3	+7.8	+7.9	+7.8	−0.5	−0.6	−0.5
27	3 36N	163 45 E	+7.3	+7.8	+7.9	+7.9	−0.5	−0.6	−0.6
28	3 25N	163 02 E	+7.3	+7.7	+7.8	+7.8	−0.4	−0.5	−0.5
28	3 11N	162 42 E	+7.2	+7.7	+7.7	+7.7	−0.5	−0.5	−0.5
29	3 01N	162 05 E	+7.2	+7.6	+7.6	+7.6	−0.4	−0.4	−0.4
29	2 56N	162 05 E	+7.1	+7.6	+7.5	+7.6	−0.5	−0.4	−0.5
30	2 28N	161 53 E	+7.1	+7.6	+7.5	+7.6	−0.5	−0.4	−0.5
30	2 20N	161 32 E	+6.9	+7.6	+7.5	+7.6	−0.7	−0.6	−0.7
Oct. 1	1 55N	160 34 E	+6.9	+7.4	+7.4	+7.5	−0.5	−0.5	−0.6
1	2 05N	160 50 E	+6.8	+7.4	+7.4	+7.6	−0.6	−0.6	−0.8
2	1 01N	160 07 E	+6.8	+7.5	+7.4	+7.5	−0.7	−0.6	−0.7
2	0 04 S	159 50 E	+6.8	+7.5	+7.4	+7.6	−0.7	−0.6	−0.8
3	1 31 S	159 43 E	+6.9	+7.6	+7.5	+7.7	−0.7	−0.6	−0.8
3	2 40 S	160 11 E	+7.3	+7.8	+7.8	+7.9	−0.5	−0.5	−0.6
4	3 46 S	160 54 E	+7.4	+8.0	+8.0	+8.0	−0.6	−0.6	−0.6
4	4 29 S	161 21 E	+7.4	+8.1	+8.1	+8.1	−0.7	−0.7	−0.7
5	4 58 S	161 48 E	+7.6	+8.2	+8.1	+8.1	−0.6	−0.5	−0.5
6	5 56 S	163 36 E	+8.2	+8.4	+8.4	+8.3	−0.2	−0.2	−0.1
7	6 31 S	164 03 E	+8.0	+8.6	+8.5	+8.3	−0.6	−0.5	−0.3
8	7 20 S	163 25 E	+8.0	+8.6	+8.5	+8.5	−0.6	−0.5	−0.5
8	8 08 S	163 09 E	+8.2	+8.6	+8.5	+8.6	−0.4	−0.3	−0.4
9	9 09 S	162 50 E	+8.5	+8.7	+8.6	+8.6	−0.2	−0.1	−0.1
9	9 44 S	162 36 E	+8.1	+8.7	+8.6	+8.7	−0.6	−0.5	−0.6
11	11 20 S	162 31 E	+8.3	+8.8	+8.6	+8.8	−0.5	−0.3	−0.5
11	12 12 S	161 28 E	+8.2	+8.8	+8.6	+8.8	−0.6	−0.4	−0.6
12	12 24 S	161 22 E	+8.2	+8.8	+8.6	+8.8	−0.6	−0.4	−0.6
12	13 01 S	160 42 E	+8.2	+8.8	+8.6	+8.8	−0.6	−0.4	−0.6
13	13 52 S	159 58 E	+8.2	+8.8	+8.6	+8.8	−0.6	−0.4	−0.6
13	14 14 S	159 19 E	+8.0	+8.8	+8.6	+8.8	−0.8	−0.6	−0.8
14	15 33 S	158 41 E	+7.9	+8.9	+8.7	+8.8	−1.0	−0.8	−0.9
14	17 02 S	158 08 E	+8.1	+8.9	+8.8	+8.9	−0.8	−0.7	−0.8
15	18 37 S	157 46 E	+8.4	+9.0	+8.9	+9.0	−0.6	−0.5	−0.6
15	20 16 S	157 24 E	+8.3	+9.2	+9.0	+9.2	−0.9	−0.7	−0.9
16	21 34 S	157 22 E	+9.0	+9.3	+9.2	+9.4	−0.3	−0.2	−0.4
16	21 50 S	157 05 E	+8.9	+9.3	+9.2	+9.4	−0.4	−0.3	−0.5
17	22 07 S	156 51 E	+9.0	+9.3	+9.3	+9.4	−0.3	−0.3	−0.4
18	23 10 S	157 00 E	+8.7	+9.5	+9.5	+9.5	−0.8	−0.8	−0.8
18	23 43 S	157 00 E	+9.0	+9.6	+9.5	+9.6	−0.6	−0.5	−0.6
19	23 55 S	156 50 E	+9.0	+9.6	+9.5	+9.6	−0.6	−0.5	−0.6
20	25 43 S	155 33 E	+9.1	+9.6	+9.6	+9.6	−0.5	−0.5	−0.5

Date	Position		Carnegie	Chart Values			Chart Corrections		
	Latitude	Longitude		Brit.[2]	Ger.[3]	U. S.[4]	Brit.	Ger.	U. S.
1915	° ′	° ′	°	°	°	°	°	°	°
Oct. 20	26 38 S	154 57 E	+ 8.7	+ 9.7	+ 9.6	+ 9.7	−1.0	−0.9	−1.0
21	27 34 S	154 32 E	+ 9.6	+ 9.7	+ 9.6	+ 9.7	−0.1	0.0	−0.1
21	28 35 S	154 30 E	+ 9.4	+ 9.9	+ 9.8	+ 9.9	−0.5	−0.4	−0.5
22	29 43 S	155 12 E	+ 9.5	+10.1	+10.1	+10.2	−0.6	−0.6	−0.7
22	30 48 S	155 54 E	+10.0	+10.5	+10.5	+10.5	−0.5	−0.5	−0.5
23	32 19 S	156 59 E	+10.6	+11.0	+11.0	+11.0	−0.4	−0.4	−0.4
23	33 48 S	157 34 E	+11.1	+11.4	+11.4	+11.5	−0.3	−0.3	−0.4
24	35 32 S	158 14 E	+11.5	+12.1	+12.0	+12.0	−0.6	−0.5	−0.5
24	35 54 S	158 48 E	+11.7	+12.2	+12.2	+12.2	−0.5	−0.5	−0.5
25	36 22 S	159 51 E	+12.9	+12.7	+12.7	+12.7	+0.2	+0.2	+0.2
26	37 00 S	160 40 E	+13.0	+13.1	+13.1	+13.1	−0.1	−0.1	−0.1
26	37 27 S	161 27 E	+13.0	+13.4	+13.4	+13.4	−0.4	−0.4	−0.4
27	38 12 S	161 47 E	+13.3	+13.7	+13.7	+13.7	−0.4	−0.4	−0.4
27	38 41 S	161 52 E	+13.2	+13.9	+13.9	+13.9	−0.7	−0.7	−0.7
28	39 14 S	161 57 E	+13.5	+14.1	+14.1	+14.0	−0.6	−0.6	−0.5
28	39 35 S	162 10 E	+14.0	+14.2	+14.2	+14.2	−0.2	−0.2	−0.2
29	41 57 S	162 26 E	+14.7	+15.1	+15.0	+15.1	−0.4	−0.3	−0.4
29	42 31 S	162 42 E	+15.0	+15.5	+15.2	+15.4	−0.5	−0.2	−0.4
30	43 58 S	163 29 E	+15.7	+16.4	+15.9	+16.2	−0.7	−0.2	−0.5
30	45 36 S	164 53 E	+16.4	+17.5	+17.0	+17.3	−1.1	−0.6	−0.9
31	46 31 S	167 20 E	+16.8	+17.9	+18.1	+18.0	−1.1	−1.3	−1.2
Nov. 2	45 14 S	172 00 E	+17.7	+18.2	+18.4	+18.0	−0.5	−0.7	−0.3
2	44 16 S	172 50 E	+17.2	+17.5	+18.1	+17.5	−0.3	−0.9	−0.3
3	43 42 S	172 59 E	+17.1	+17.1	+17.8	+17.3	0.0	−0.7	−0.2

Department of Terrestrial Magnetism,
Carnegie Institution of Washington.

BIOGRAPHICAL SKETCH OF AKSEL STEEN.

The well-known Norwegian meteorologist and magnetician Aksel Steen died of apoplexy on May 11, 1915. He was born at Christiania on June 26, 1849, was admitted as a student at the Royal University of Christiania in 1867, and took his degree in physical science in 1873. The next year he was appointed assistant at the Meteorological Institute in Christiania. He became assistant-director of the Institute in 1900, and on Professor Mohn's retirement in 1914, its director.



In addition to his own particular subject,—meteorology—Aksel Steen was an ardent student of the sciences that embrace terrestrial magnetism and kindred subjects. The immediate cause of his taking up work in the latter field was his post as director of the Norwegian station at Bossekop, 1882-1883, where studies of terrestrial magnetism and of the aurora borealis were made. The two volumes[1] on the work achieved at this station were prepared under Steen's direction and editorship. Important experiences connected with the carrying out of the magnetic observations at Bossekop were also published by him.[2]

In 1892 Steen was granted a public traveling scholarship, and he thus visited the most important magnetic observatories of northern Europe. On his return home he submitted a carefully prepared plan for the erection of a modern magnetic observatory in Norway. The plan, however, was never realised. On several subsequent occasions, e. g. in 1905, Steen urged the importance of erecting a permanent geophysical station at Bossekop. As is known, such a station was not erected until 1911, and then not at Bossekop, but, through the initiative of Professor Birkeland, on the summit of Mount Hallde (900 meters altitude), 13 kilometers west of the former place.

Aksel Steen also did important work in the preparation and subsequent editing of the magnetic material of the Norwegian Polar expeditions of Nansen and Sverdrup. Unhappily death overtook him before he had completed his reductions and discussion of the magnetic observations made on Roald Amundsen's Northwest Passage[3] in the *Gjöa*.[4]

In addition to being a man of science, Aksel Steen possessed marked administrative talents. Personally, he was an extremely charming and faithful friend, always ready to appreciate scientific progress, but at the same time rigid in his judgment of what he regarded as unproved assertions, or the premature announcement of results that were still awaiting confirmation.

C. S.

[1] *Beobachtungsergebnisse der Norwegischen Polarstation Bossekop in Alten, Christiania, 1887-1888.*

[2] *Bestimmung der Horizontalintensität vermittelst des Lamontschen Unifilarapparates mit festen Deflektoren;* printed in *Mitteilungen der internationalen Polarcommission, Part 4, St. Petersburg, 1883, p. 152.*

[3] See *Terr. Mag.* v. 20, p. 75.

[4] Among Steen's later publications may be mentioned: *The Diurnal Variation of Terrestrial Magnetism;* in *Videnskabsselskabets skrifter*, 1904.

LETTERS TO EDITOR

SOME NOTES ON THE OCCURRENCE OF THUNDER AT SEA.

It appears that Baron von Humboldt is responsible for the statement that thunder is never heard on the ocean at any great distance from land, though violent thunderstorms are often observed at sea and vessels are frequently struck by lightning.[1] Since this statement has provoked discussion from time to time, the following notes made from the *Carnegie* observations, received from Captain J. P. Ault, may be of some interest. In accordance with directions issued to the vessel by the Director of the Department of Terrestrial Magnetism, the observations were made on the way from Dutch Harbor, Alaska, to Port Lyttelton, New Zealand, between August 6 and November 2, 1915. As the special object was to obtain some facts on the sound of thunder at sea, it is not likely that thunder audible at the ship occurred without being noted.

Lightning storms or displays were seen on twenty-two different occasions and they were accompanied by thunder on only six occasions, briefly described as follows:

1. At 8 P. M., August 20, a low, distinct crash and rumblings were heard 7 seconds after the lighting flashes seen in the west. The nearest lands were the small but rocky island of Attu, of the Aleutian group, about 240 nautical miles distant in a northeasterly direction, and Kamchatka, about 420 miles in a northwesterly direction.

2. From 11 P. M., September 29, to 2 A. M., September 30, blinding lightning flashes were seen at altitudes of about 30° toward the northeast around to the northwest. Only one thunder peal was heard, which was noted at 1:30 A. M., September 30. The high islands of the Solomon group were the nearest lands at the time, 600 miles away in a southwesterly direction. A gentle easterly zephyr was recorded at the time.

3. Again, near the same group, rolls of thunder were heard with lightning flashes in the northwest at altitudes ranging from 0° to 50°, on October 7, from 2 A. M. to 5 A. M. A very light breeze blew from the south at the time. The islands were 250 miles to the southwest.

4. On October 8, about 5 A. M., heavy rolls of thunder were again heard 140 miles east of the Solomon Islands. Lightning flashes were observed toward the east at altitudes varying from 0° to 60°.

5. A heavy roll was heard on October 10 at 9:30 A. M., when *no* lightning was seen. It was followed 15 minutes later by vivid streaks

[1] *Scientific American*, New York, vol. 112, No. 25, June 19, 1915, p. 605.

of lightning from north to northwest, accompanied by loud thunder claps. The lightning streaks were seen at various altitudes from 0° to 80°. The first claps of thunder occurred about 20 seconds after the flashes, and the interval gradually decreased to 4.5 seconds, to grow to about 20 seconds again, corresponding to an approach and retiring of the storm. The nearest land was the Solomon group, 50 miles to the west.

6. Thunder was heard during a squall 450 miles northwest of the high land of South Island, New Zealand, on October 27, at 8 P. M., the lightning flashes occurring from 70° altitude to the horizon, in the north-northwest.

There was no record made of an occurrence of *streak*-lightning *without* the *accompanying* thunder on the passage from Dutch Harbor to Port Lyttelton.

Flash and sheet lightning unaccompanied by thunder were seen on one occasion as high as 70°, but usually the recorded angular altitude was not above 35°.

One who has heard the reverberation of thunder in the narrow gorges of a rocky mountainous district will hardly question that the intensity of thunder is increased in such a locality, and sheet lightning is now admitted to be the reflected flashes of an ordinary lightning storm too distant to be heard.

It might then be inferred from the *Carnegie's* record of thunder and lightning storms between Dutch Harbor and Port Lyttelton, that many lightning storms with accompanying thunder are too distant to be heard even on a sailing vessel where there is frequently no noise to mask the sound.

Several times lightning unaccompanied by thunder was seen in calm weather and only once was it seen when the wind force exceeded 4 of the Beaufort scale. From which it may be concluded that the noise on ship is not the reason for the apparent silence of some thunderstorms at sea.

The record shows, however, no greater distance than 600 nautical miles from land, which in this case was of such mountainous character as would tend to intensify the thunder.

An important fact may be deduced from one of the recorded storms. It is that the varying time interval between flash and clap recorded in the lightning storm of October 10, clearly indicated the approach and recession of the storm, and indicates that the thunder was lost to the *Carnegie's* observers when the storm was over 5 miles distant, as determined by the first and last intervals of about 20 seconds.

The facts noted on this passage of the *Carnegie* are yet too few to warrant any final conclusions. It is expected that additional data will be available before the present cruise will have ended.

W. J. PETERS.

DEPARTMENT OF TERRESTRIAL MAGNETISM,
CARNEGIE INSTITUTION OF WASHINGTON.

THE GEOGRAPHIC AND MAGNETIC SURVEY OF THE SOUTHERN PART OF BRAZIL.

The work accomplished by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington on the Atlantic Coast and along the large rivers, the Amazon and Parana, has led the writer to inaugurate a similar work in the interior of Brazil for the purpose of facilitating the construction of a chart of the magnetic elements. Accordingly, in 1910-1911, Mr. Domingos Costa, Assistant of the First Class, carried out a magnetic and geographic survey from Rio de Janeiro to the mouth of the S. Francisco. A summary of the results of this expedition first appeared in *Terrestrial Magnetism and Atmospheric Electricity* (Vol. XVII, No. 3) and later, a report, in more complete form, was published in a volume issued by the Observatory of Rio de Janeiro, in 1914, under the title "*Levantamento Magnetico do Valle do Rio S. Francisco.*"

As a continuation of this first work it was decided, with the permission of the Minister of Agriculture, to send across country as far as Matto Grosso, another expedition, which, on the return trip, was to descend the Rio Uruguay and pass through the states of Rio Grande, S. Catharina, Paraná, S. Paulo, and Rio de Janeiro, thus completing a circuit embracing a vast continental area. Mr. Herminio Fernandes da Silva, to whom this work was assigned, set out from Rio on June 17, 1913, and reached Itapura, on the frontier of Matto Grosso, on the 2nd of the following December, having determined the geographic position and the magnetic elements at a great many points. The company which was at that time constructing the railway line known as the "Noroeste do Brazil," had nearly finished the work of grading along its entire length, and it was hoped that by following this road the journey would be less difficult, but a series of strikes and the falling of temporary bridges over the rivers to be crossed, made it necessary to change the itinerary. The observer returned to Sorocaba (in the State of S. Paulo) and started again across the southern states, thus reversing the direction of his journey. However, new obstacles impeded the progress of the work. Revolts of Indians and natives of the unapportioned territory lying between the states of Paraná and S. Catherina obliged the observer to proceed rapidly and not without danger. Having finished the survey of the State of Rio Grande, he returned to Rio on March 15, 1915. He then went to the observatory at Vassouras, where the Eschenhagen magnetographs were beginning to function regularly, to compare his instruments.

The instrument used for the astronomical work was a portable Heyde theodolite provided with a telescope having a 32 mm. aperture and a 25 cm. focal length. The circles, 17.5 cm. in diameter, are protected against dust by a cover and each is read by two microscopes which permit an approximation of 2″.5.

Ten chronometers were used for carrying the time in localities not in telegraphic communication with Rio de Janeiro. Of these chrono-

meters, two, Leroy No. 1065, and Ditisheim No. 28224, are of the normal marine type, and the other eight are torpedo boat watches, made by Nardin, Leroy, and Ditisheim.[1]

In general, the methods of observations were as follows:

For azimuth, the method of the elongations of the circumpolar stars, for which the Observatory of Rio de Janeiro has published tables which greatly simplify the work;

For time, the method of equal altitudes of stars of slight declination, on both sides of the meridian, the so-called Zinger method. A list of stars satisfying the requisite conditions, and for the southern hemisphere, was published by Mr. Obrecht, Director of the Observatory of Santiago, Chile. This catalogue is very convenient but, unfortunately, the edition is at present exhausted;

For latitude, Sterneck's method, consisting in a simplification of that of Talcott, which renders it more easily applicable to small instruments.

As to the precision of the results, we may assume the following values for the error in the different elements: *Latitude*, less than a second of arc; *telegraphic longitude*, 0.2 of a second, and for those obtained from the transportation of time, 1 second; *azimuth*, 3″ to 5″.

Determinations were made with Barrow circle No. 114, for inclination and with magnetometers Nos. 18 and 20, Indian Pattern, made by Cooke & Sons, for declination and horizontal component. These instruments were tested at Kew Observatory where their constants were determined.

These are the instruments which were used on the S. Francisco expedition, and as on the first occasion, the lenses of the collimator became loose during the observations at Sorocaba. This fortunately occurred when the instrument could be readily replaced. The work as far as this city was carried out with magnetometer No. 20 which was then replaced by No. 18. The observations obtained at Sorocaba do not manifest, fortunately, any notable divergence.

The methods used for the magnetic work were those recommended in the "Manual for Scientific Enquiry" of the British Admiralty, with certain modifications mentioned in Daniel Hazard's work "Directions for Magnetic Measurements."

It was possible to obtain the value of the annual changes for the five following stations only, for which sufficiently exact previous values were known, namely: Barra do Pirahy, Vassouras, Itaquy, Uberaba and Porto Alegre.

H. Morize.

[1] The stations at which the longitude was telegraphically determined are: Rezende, Vassouras, Taubaté, Sorocaba, Jundiahy, Ribeirão Preto, Franca, Ponta Grossa, Herval, Passo Fundo, Cruz Alta, Santa Maria, Alegrete, Itaquy, S. Gabriel, Bagé, Pelotas, R. Pardo, Cachoeira and Araguary.

National Observatory, Rio de Janeiro,
November 24, 1915.

ON THE LUNAR-DIURNAL VARIATION OF THE MAGNETIC DECLINATION AT ZI-KA-WEI.

The September 1915 issue of the Journal, p. 139, contains an abstract of papers by Dr. S. Chapman on the lunar-diurnal variation of the Earth's magnetism. The following notes, in which an analogous question is considered with less detail, may be of interest.

In this discussion, we have limited ourselves to the consideration of the diurnal amplitude of the declination because this element is measured here every day photographically, and we are thus made independent of all computation. By diurnal maximum and minimum we understand that the elongations which take place at midday and toward sunrise, are meant. A larger value, which might occur at another hour, would be considered as belonging to another phenomenon.

The entire series of 31 years, during which the magnetic service of Zi-ka-wei has existed, has been revised and certain slight errors have been corrected. We have been led to divide this series into three cycles:

March 1877 to December 1886, nearly 10 years;
January 1887 to December 1896, 10 years;
January 1897 to March 1908, 11 years, 2 months.

Letting A and P denote the diurnal amplitude of the times of the lunar apogee and perigee, respectively, we have determined these values by periods of 5 days for the first and second cycles, and by periods of 3 days for the third cycle, which is a complete solar cycle. The dates were in Zi-ka-wei local time. It is possible that, in a small number of cases, in the first cycle, we have made an error of a day in determining the date of a perigee or of an apogee. The ephemerides of that period gave only the day and we considered it unnecessary to compute the hour.

Each vale of A and of P was determined for an entire year (14 months in 1907-8), or about 13 anomalistic revolutions of the Moon, so as to eliminate the annual variation of the amplitude which is large.

Each of the three cycles, but not each year, has given for P a number larger than for A. These numbers are:

1st cycle.	$P = 5'.553 \pm 0'.208$;	probable error: $0'.658$	$\frac{P}{A} = 1.010$
	$A = 5'.500 \pm 0'.155$;	" " $0'.489$	
2nd cycle.	$P = 5'.838 \pm 0'.140$;	" " $0'.445$	$\frac{P}{A} = 1.029$
	$A = 5'.675 \pm 0'.161$;	" " $0'.510$	
3rd cycle.	$P = 5'.126 \pm 0'.137$;	" " $0'.476$	$\frac{P}{A} = 1.023$
	$A = 5'.012 \pm 0'.099$;	" " $0'.344$	

In order to have a total, giving to every year the same weight, although the first cycle is inferior, for the reason we have just given, we find:

$$\frac{P}{A} = 1.0226 \pm 0.0068 \text{ ; probable error: } 0.0378.$$

These numbers are slightly smaller than those obtained by Dr. Chapman. At all events, the fact that the diurnal amplitude is greater at the lunar perigee than at the apogee appears well confirmed.

Lu-kia-pang, *January 28, 1916.* J. de Moidrey, S. J.

CRUISE OF THE *CARNEGIE* FROM LYTTELTON, NEW ZEALAND TO SOUTH GEORGIA, DECEMBER 6, 1915, TO JANUARY 12, 1916.

I beg to transmit the following report on the trip of the *Carnegie* from Lyttelton to South Georgia, December 6, 1915, to January 12, 1916.

For the first week after leaving Lyttelton the winds were mainly from the SSW., forcing us considerably to the eastward of our route. So much so that we sighted the Antipodes, bearing south, distant 20 miles, on December 9, and would have passed over the charted position of the Nimrod Group had the wind remained in the south another twelve hours. I had not intended to go near this group, but the adverse winds sending us so near them I decided to stand on toward the east another day, to endeavor to sight them, but the wind shifted to the north twelve hours too soon and we passed 40 miles to the SW. of the position.

On December 7, a mirage presenting the appearance of distinct and extensive land was seen in the west, in the direction of Banks Peninsula, which was 190 miles distant at the time.

We crossed the 180th meridian December 9, so repeated the date as December 9 (*2*). Our first piece of ice was sighted on December 18, lat. 60° 12′ S., long. 150° 46′ W., and on December 19, 30 icebergs, some being over 400 feet high and 1 mile long, were passed. We had snow on December 18, 19, 20 and 21, and rather wintry weather. The barometer dropped to 28.26 inches on December 18 during the snow storm. No icebergs were seen after December 24 until January 10, just before arrival at South Georgia, when 8 or 10 good sized bergs were passed.

As our route lay near the charted position of Dougherty Island, we determined to look for it. On the afternoon of December 24, the cry of "land ahead" was given and we saw what appeared to be a bold, dark rock island. Immediately our course was shaped to pass near it. Everyone was convinced that either a new island had been discovered or that the position given for Dougherty Island was very much in error. It seemed to be a rocky cliff with a snow cap. Nearer approach, however, proved that the supposed island was an iceberg, 225 feet high by ¼ mile long. The light was reflected from the perpendicular ice-wall in such a way as to give to the berg the appearance of a huge dark rock. The morning of December 25 found us within three miles of the position given for Dougherty Island. The weather was cloudy but the seeing was good. Nothing could be seen from the masthead. I went aloft myself every half hour while we were passing the position given for the island. Had anything over 100 feet high been within 35 miles of the vessel in any direction we would have seen it. At 3:40 A. M., Decem-

ber 25, Dougherty Island should have been 3 miles SE. of us. There was nothing visible within a radius of 35 miles at the time. The island has either been very much mislocated, or it has disappeared, or possibly it was an ice-island. Our experience on December 24 would confirm the possibilities of optical illusions. The *Carnegie's* track extended from lat. 59° 28′ S., long. 123° 17′ W., to lat. 59° 08′ S., long. 110° 10′ W.; daylight and good seeing were had all the time. If any one else attempts to locate the island, he should try either 40 miles south or 40 miles north of the charted position. We assumed the island to be at 59° 21′ S., and between 119° 10′ W. to 120° 20′ W.

December 30 and 31 were the first fine days experienced since our departure from Lyttelton. In spite of storms, rain, snow, fog and prevailing cloudy weather, we succeeded in getting declination observations daily, and averaging twice daily during the entire trip. This was accomplished by taking advantage of every opportunity and spending considerable time standing by. Frequently we would make six or more trips to the bridge before being successful. At other times observations would be made during the only five or ten minutes that the Sun was visible on the entire day.

The winds were mainly from the westerly semicircle, north and northeasterly winds with high and falling barometer, shifting to northwest and west when the barometer began to rise; rain and mist occurred nearly every day. Fogs were quite frequent, but not of long duration.

The entire party has enjoyed the very best of health, and the weather has not been very severe. It has been more enjoyable in fact than a trip through the hot tropics.

I cannot speak too highly of the patience and good-will shown by the entire party in the unusual efforts that had to be made to get declination-observations—called as they were at all hours of the day and night, out of a warm bed into the cold and rain of the outdoors, many times without accomplishing anything and often waiting on duty in the hope of obtaining better results later. (See also Note 3, p. 28, of this Journal.)

The total run from Lyttelton to South Georgia was 5440 miles or an average of 144 miles for 37.9 days; the total distance logged was 6010 miles. We arrived January 12, 9:30 A. M., going the last 24 hours under our auxiliary power.

J. P. Ault,
Master of the Carnegie.

On Board the "Carnegie,"
King Edward Cove, South Georgia,
January 12, 1916.

NOTES

1. Principal magnetic storms recorded at the Cheltenham magnetic observatory, July-December, 1915. The following data have been received through the Superintendent of the United States Coast and Geodetic Survey:

Latitude 38° 44'.0 N: longitude 76° 50'.5, or $5^h\ 07^m.4$ *W. of Greenwich.*

Greenwich Mean Time				Range		
Beginning 1915		Ending 1915		D (Declination)	H (Hor'l Int.)	Z (Vert'l Int.)
	h m		h	′	γ	γ
Sept.	22, 10 18	Sept.	30, 11	30.7	147	92
Oct.	14, 13 46	Oct.	16, 5	38.0	158	171
Oct.	23, 12 47	Oct.	26, 3	32.2	158	102
Nov.	5, 14 36	Nov.	6, 24	42.7	148	278
Nov.	15, 20 12	Nov.	21, 3	29.9	134	103
Dec.	6, 11 31	Dec.	7, 4	27.8	154	98

2. Magnetic work in South Australia by G. F. Dodwell, 1914-15. In the latter part of 1914 the government astronomer of South Australia, Mr. G. F. Dodwell, working in co-operation with the Department of Terrestrial Magnetism, obtained a valuable series of magnetic stations on his astronomical expedition to the Musgrave Ranges in South Australia. With a magnetometer (C. I. W. No. 6), lent him by the Department, and a Barrow dip circle (No. 38) furnished by the Government Observatory of New South Wales, he determined the 3 magnetic elements at 7 main stations, the declination and horizontal intensity at 1 station and the declination at 1 station. With a tested trough compass theodolite he furthermore observed the approximate declinations at 20 substations. During the latter part of 1915 magnetic observations were made at Roseworthy, Kapunda, Gawler, and Angaston.

3. Cruise of the Carnegie, 1915-16. According to cable information received via Buenos Aires, the *Carnegie*, under the command of Captain J. P. Ault, arrived at South Georgia Island on January 12, having made magnetic observations daily since her departure from Lyttleton, New Zealand, on December 6. Icebergs were encountered on nine days during the trip. The *Carnegie* sailed again on January 14, in continuation of her circumnavigation of the region between the parallels 50° and 60° south. (For additional information, see p. 26.)

4. *World Isogonic Chart for 1915.* This new chart (No. 2406) of the United States Hydrographic Office shows various improvements on previous editions. The data utilized were those obtained by the Department of Terrestrial Magnetism, on land and at sea, as well as those of other organizations and observatories.

5. *United States Isogonic Chart for 1915.* The 1915 edition of the special publication (No. 33, serial No. 18; U. S. Coast and Geodetic Survey) on "The Distribution of the Magnetic Declination in the United States, with Isogonic Chart and Secular Change Tables," has been issued. The secular change tables give tabulated values of the declination from 1750 to 1915, by 10-year intervals, for from one to four points in each State. On the new isogonic chart, wherever it was found impossible to represent the large local disturbances by continuous lines, disturbed areas of limited extent are shown in closed curves and abnormal declination-values are entered on the chart. The chart makes a very creditable appearance.

6. *Second Pan-American Scientific Congress.* This highly successful Congress, consisting of delegates and members from the various North and South American republics, met in Washington, December 27, 1915—January 8, 1916. Among the resolutions passed of particular interest here are the following: The American republics undertake as soon as possible: (a) Accurate geodetic measurements which may serve to determine the limits, national and international, and to contribute to the discovery of the true shape of our planet; (b) magnetic measurements of their respective surfaces and the establishment of several permanent magnetic observatories; (c) to extend their gravimetric measures (obtained by means of the pendulum) to those regions where these measurements may not have been taken.

7. *Comparisons of magnetic standards at Washington, 1915.* During November and December, 1915, Mr. C. A. French of the Dominion Observatory (Ottawa, Canada), and Mr. W. E. W. Jackson, of the Canadian Meteorological Service (Toronto), compared the magnetic instruments of their respective organizations with the standards of the Department of Terrestrial Magnetism.

8. *Personalia.* We regret to record the following deaths in 1915: *Julius Ritter von Payer* (age 73 years), the well-known Polar explorer; *Dr. M. A. Veeder* (age 68 years), whose vivid interest in auroral studies will be recalled; *Capt. R. Bage* (killed in July at the Dardanelles), a highly valuable member of the Mawson Antarctic Expedition, rendering especially noteworthy service on the journey to the vicinity of the South Magnetic Pole.

D. L. Hazard has been appointed Chief of the Division of Terrestrial Magnetism of the United States Coast and Geodetic Survey, and *J. M. Seybolt* was made Assistant Chief in the same division.

9. *Editorial notice.* Subscribers who desire the mailing of their copies deferred until the close of the war, should give prompt notification. The Journal cannot assume the risk of loss of copies by mail. (See notice on second page of cover.)

ABSTRACTS AND REVIEWS

BEATTIE, J. C.: *The Magnetic Survey of South Africa.*[1]

During the years 1910-1913 the magnetic survey of South Africa was continued by the author, supported by a grant-in-aid from the Union Government, for the double purpose of extending the survey over new areas, and of determining the secular variation in those parts for which a suitable time-interval since the earliest observations were made, could be secured. In the (southern) summer 1910-1911, observations were made in the East Transvaal between the railways; in 1911-1912 the survey was extended over a portion of British Bechuanaland mainly east of the Kuruman Mountains; in 1912-1913 a part of the Bushmanland was covered. On each expedition various repeat stations were occupied, while others were visited in the winter months. Altogether about 80 stations were occupied; at most of these all three elements were determined, and about 16 were reoccupations. The report also includes several declinations obtained in East Transvaal by Mr. O. C. McPherson during the progress of a railway survey. The instruments and methods employed by the author are in general the same as in the earlier work, which are described at length in his "Report of a Magnetic Survey of South Africa" (J. C. Beattie, London, 1909). The summary of results is given without correction for diurnal or secular variation.

The results of observations made at various times from 1900 to 1913 within a region lying mainly west of the 24th meridian and south of the 26th parallel, together with a smaller area southwest of Pretoria and Mafeking, have been collected for the purpose of drawing with their aid lines of equal magnetic declination, inclination, and horizontal intensity. There are 255 stations thus tabulated with the results reduced to the epoch July 1, 1908 by means of suitably chosen repeat stations. No attempt was made in any case to correct for diurnal variation. Three isomagnetic charts, one for each element, are presented for the western portion of the Union of South Africa, though that for the horizontal intensity covers a more restricted area than the others. It is unfortunate that the author did not find it practicable to choose a later epoch so that the information would be more immediately available, particularly in view of the very large annual changes that he shows in the next paper to be taking place over that region.

The study of the secular variation in South Africa possesses unusual interest because of the large value it has attained in the case of each of the three elements. The change in the declination seems to be

[1] Further Magnetic Observations in South Africa. Cape Town, *Trans. R. Soc. S. Afric.*, v. 4, Pt. 1, 1914. True Isogonics, Isoclinals, and Lines of Horizontal Intensity for the Northwestern Part of the Union of South Africa and for a Part of Great Namaqualand for the Epoch July 1, 1908. *Ibid.*, v. 4, Pt. 1, 1914. The Secular Variation of the Magnetic Elements in South Africa during the Period 1900-1913. *Ibid.*, v. 4, Pt. 3, 1915.

larger than in any other part of the world so far as known, with the exception of the northeastern coast of Brazil. In the preparation of the chart showing lines of equal annual change in declination, the author has been able to make use of other information than that from his own work; for example in the extension of the lines over the Indian Ocean, the *Gauss-Carnegie* comparisons were utilized. The lines of equal annual change of declination run parallel to the coast as far north as Madagascar, with the largest values near the coast, diminishing toward the northwest. From a comparison with the British and American charts the author conceives these lines returning through the Indian Ocean, forming narrow closed ovals, with a center of high maximum change, about 12 to 13 minutes easterly, just off the mainland. That the change has been increasing continuously for a long time is shown by a series of graphs in which the declination and the year of observation are the co-ordinates. The graphs for the various selected stations show a similar curvature, indicating a continuously increasing rate of change. It follows therefore that the annual change at the time of the preparation of the paper was considerably greater than that shown on the chart, since the chart-values are averages over the intervals between the earliest and latest observations. This may be illustrated in the case of Cape Town, for which the value on the chart is —8′, that is, a decreasing westerly declination of 8 minutes per year. Referring to the tables accompanying the chart it is seen that the whole change from 1901.0 to 1914.0 was 1° 44′.7, or a little more than 8′ per year, while the change from 1908.8 to 1914.0 was 51′.8, or very nearly 10′ per year. A similar result is obtained from examining stations in other parts of the country. The charts therefore would have received additional value if an epoch had been possible to which the figures for all the stations could have been referred. As it stands the figures for different stations refer to different dates, falling variously between 1904 and 1911.

The inclination seems to have had a more uniform rate of secular change, though its value is also large over the southern portion of the continent, varying from about 8′ increasing southerly dip at Cape Town to about 5′ along a line from Delagoa Bay to Loanda, and 2′ at Dar-es-Salam. The line of no change seems to follow approximately along a meridian near the west coast of Madagascar, the annual changes at Tananarive and Mauritius having opposite signs.

No attempt was made to draw the lines of equal change in the horizontal intensity, though it may be stated generally that it approaches 90 gammas over Cape Colony with a marked tendency to diminish northward toward Rhodesia. Some of the later values obtained exceed 100 gammas, with evidence that there has been an increase during recent years. The chart presents the annual change in gammas plotted at the stations, each value being a mean as in the case of the declination.

The author has appended tables of all the values used in the preparation of the charts, so that the annual change for a desired epoch may be obtained by any one interested. The three papers thus make a most interesting and valuable addition to our knowledge of the magnetic condition of South Africa.

H. W. Fisk.

SCHMIDT, ADOLF: *Ein Lokalvariometer für die Vertikalintensität.*[1]

The best means for determining the vertical intensity is found in the magnetic balance. The approximately horizontal magnet of the latter indicates directly, through its changing inclination, the deflections of the vertical component from an arbitrarily chosen normal value. The so-called Tiberg-Inclinator, used in Sweden in search for iron ore deposits, represents one variety of magnetic balance, in which the needle, suspended in pivot bearings, is kept in an approximately horizontal position by means of a suitable arrangement for displacing the center of gravity.

The local disturbances encountered ordinarily, being seldom more than 0.03 C. G. S., or 3000 γ, and usually very much less, require for their measurement an instrument very much more sensitive than the one mentioned above, and the idea of a magnet resting on a knife-edge suggests itself. Though systematic experiments are lacking that would prove the superiority of either the knife-edge bearing or the pivot bearing, there is nevertheless a difference between the two in favor of the former. Next to a suitable optical arrangement an extremely careful and accurate mechanical execution is of prime importance. There are two principal causes of disturbances or troubles apt to occur in magnetic balances: 1) displacement of masses within the magnetic system, and 2) uncontrollable occurrences at the knife-edges and bearings. It is to be remembered that changes in the relative position of center of gravity and center of rotation amounting to a few $\mu\mu$ (*i. e.* 0.000001 mm.) influence the reading perceptibly.

In the experimental instrument made by O. Töpfer in 1907 every precaution had been taken to prevent the troubles mentioned. Adjusting weights for levelling the magnet system had been omitted in order to avoid accidental shifting of the center of gravity. The magnet of needle No. 1 was shaped out of one solid piece of steel and the upper surface of the connecting bridge between the two blades had been highly polished so as to serve as a reflecting mirror. The whole needle consisted therefore of only two pieces, namely: the two-blade magnet and the prism with the knife-edges, the danger of accidental displacement of the center of gravity being thus reduced to a minimum. The manufacture of this needle, however, presenting great difficulties, needle No. 2 was made in the usual way, consisting of two separate blades screwed to a brass connecting piece, and with the mirror cemented on the top. This needle proved to be very satisfactory, though the sensitiveness was only about one fourth that of No. 1.

Knowing by previous experience that neither agate nor iridium would be suitable for the knife-edges and bearings, an experiment was made with quartz and it proved to be successful, the balance showing a permanence of position never before attained. It is to be noticed that

[1] Repr. Berlin, *Veröff. met. Inst.*, No. 284, 1915 [(109)-(134)].

the arresting-device was so constructed as invariably to bring exactly the same portions of the knife-edges and bearings in contact with each other. The quartz bearings were made in the shape of cylinders with their axes horizontal and at right angles to the knife-edges. The magnet-house consisted of a cylindrical box, the bottom carrying the magnet-bearings, and the top supporting a telescope with a Gauss eye-piece and an eye-piece scale; also a level of a sensitiveness of $1'$. The damping-arrangements consisted of two removable copper dampers with openings for the insertion of thermometers. Two arresting-devices had been provided, one for lifting the needle off the bearings and the other for clamping the needle securely in position for transportation.

The tripod head, consisting of three principal parts, contained suitable arrangements for levelling; the top plate, being revolvable, carried a graduation in whole degrees and could be set in the magnetic meridian by means of a compass-attachment, before the variometer proper was put in place. A bar magnet, inclosed in a wide tube with a thermometer attached to it, could be fastened vertically under the instrument, thus enlarging the range of measurements.

In the first instrument made, the telescope on top of the magnet-house was revolvable around a vertical axis for experimental and testing purposes; in future instruments the telescope might be fastened permanently to the magnet-house at right angles to the needle. The eye-piece contained a scale of 40 divisions of $5'$ angular value each, corresponding to a change of level of the magnet mirror of $2'.5$. The first, last and center lines were made longer and were read as 0, 20, and 40, beginning at the north end of the needle, while the reflected scale was read in opposite direction as (40), (20) and (0).

The method of observation is simple and consists chiefly of reading the difference between the direct and reflected images of the scale in the telescope, taking the temperature and reading the level.

Comments on the theory of the instrument, the results of a number of tests and experiments and some notes on the determination of the damping, sensitiveness, temperature coefficient, etc., are also given.

J. A. WIDMER.

DALE, J. B.: *The Resolution of a Compound Periodic Function into Simple Periodic Functions.*[1]

The method proposed for analyzing a set of numbers (for finding the periods by solving an equation of the n^{th} degree) is one form of attack upon the problem through the "reeurring series" properties of numbers $T_m = \Sigma_k B_k \sin(b_k + m\beta_k)$. Introducing the operator $E[a_r] = a_{r-1} + a_{r+1}$ Dale is able to write a Z-equation whose roots are double the cosines of β_k in an elegant determinant form. He shows how to get the phases and amplitudes, formulas being given into which to substitute

[1] Repr. London, *Mon. Not. R. Astr. Soc.*, v. 74, No. 7, May, 1914 (628-648).

the T's. He gives a criterion for the number of periods as follows: If the numbers are of periodicity n, then a certain determinant Δ of order $n + 1$ must vanish. He shows that if Δ'_n is any minor of this Δ_{n+1}, then $\frac{\Delta_{n+1}}{\Delta'_n} \cdot \quad 4^n$. This criterion is not absolutely necessary, for Dale overlooks the possibility of p' being in error as well as the data terms. This 4^n is in terms of the last unit in error.

Dale applies his method to two problems. The first is composed of data computed for 7 terms of $y = 2 + \sin(30°t) + 2 \sin(40°t + 20°)$. He gets for this:

$$y = 1.9789 + 0.9772 \sin(29°.11t + 2°.45) + 2.030 \sin(40°t + 19°.08).$$

The second problem is a study of Newcomb's "Minor Residuals" in the fluctuations of the Moon's mean motion. He works this assuming it to be a P_2 function.

At the close he gives a set of formulas useful in the reduction of a reciprocal equation to one of half the degree. In section 8 he gives a method for estimating the values of predominant periods. The theory is analogous to the reviewer's when seeking for best P_1 *and* P_2.

G. N. ARMSTRONG.

CHREE, C.: *The 27-Day Period in Magnetic Phenomena.*[1]

The author has shown in two previous papers that there is a decided tendency for the "magnetic character" of a day to resemble more closely that of a day 27 days before or after, than that of the average day. It is not claimed, however, that there is a period of this length in the strict sense of the word, that is, that the phenomena go on repeating themselves indefinitely. "Character" figures were used mainly in these earlier papers as the measure of magnetic disturbance.

An examination of the years 1894 and 1895, using the range in H as a measure of disturbance, brought out the 27-day period as unmistakably in the range figures as in the character figures for 1895, but for 1894 both the character figures and range figures pointed to a period of about 30 days. It was therefore considered desirable to undertake this investigation, using as measures of disturbance the ranges in all three elements, D, H and Z.

The work is based on the Kew results for the 11 years 1890-1900. The five days in any month which had the largest daily range in an element, are taken as the five most disturbed days of that month for the element in question. Omitting December 1900, since 27 days later carries over into 1901, there are 10 years and 11 months, or 131 months, with 5 most disturbed days each, giving 655 most disturbed days for each element for the period under discussion. Likewise 655 quietest days are taken, using in this case the five days a month which the Astronomer Royal had selected as representative quiet days. There

[1] Repr. London, *Proc. R. Soc.*, A, v. 90, 1914 (583-599).

are thus for each element 60 selected most disturbed days for each of the first 10 years of the 11-year period, and 55 such days for the last year. The quietest days are distributed in exactly the same way.

For a year the average daily range of an element is taken for the 60 selected most disturbed days of that year, and also for 10 other groups of 60 days each, as follows: the four groups made up of the days 1 and 2 days before and 1 and 2 days, respectively, after the selected most disturbed days; and the 6 groups made up of the days 25 to 30 days, respectively, after the selected most disturbed days. For the year 1900 the groups are made up of 55 days instead of 60. These 11 average range values are finally expressed as percentages of the mean range of the element in question for all the days of the year. The quietest days are treated in exactly the same way. Three tables are then made of the percentages, one for each of the elements D, H and Z. Each table is separated into two parts, one for the disturbed days, and one for the quiet days, and each part contains 121 values, one for each of the 11 groups of days in each of the 11 years. In addition, the 11-year means are also given in each table for the 11 groups, both for the disturbed and quiet days, making a total of 132 percentage values in each part of each table. A fourth table is formed by taking the means of the corresponding values in the D, H and Z tables.

The separate D, H and Z tables and the table of combined results give strong evidence of the 27-day period, especially in the case of the 11-year means. There is some discussion of contradictions in the years 1892, 1894, and 1900, 1892 and 1894 being the most disturbed years of the 11-year period, and 1900 a very quiet year of marked decline in disturbance. To avoid the effect on the results of seasonal change in the daily range, a table is made up of the excesses of the 11-year means of the percentages for the disturbed and associated days over the corresponding values for the quiet and associated days, taking the differences in the separate D, H and Z tables and also in the table of combined D, H and Z values. Corresponding values are added from the international "character" figures for the years 1906-1911. This table of 5 values for each of the 11 groups of days, covering the years 1890-1900 for the range figures, and the years 1906-1911 for the international "character" figures, shows the 27-day period without exception, and indicates that it is in excess of 27, but nearer 27 than 28.

If five days were selected by lot from each of the 131 months, it would be expected that in 108 cases the 27th day before or after a selected day would itself be a selected day. For the disturbed days the actual numbers are 164 for D, 186 for H, 169 for Z, and 173 for D, H and Z. There are 153 cases of such a sequence of 2 quiet days. A quiet day was followed 27 days later by a disturbed day in H 57 times, while a disturbed day in H was followed 27 days later by a quiet day 72 times. The result of tracing 27-day sequences in the H-disturbed days is as

follows: 2 days or more, 186 cases; 3 days or more, 32; 4 days or more, 17; 5 days or more, 7; 6 days or more, 2; 7 days or more, 1; 8 days, 1. It is to be borne in mind that the number of recurrences of a phenomenon at intervals of an integral number of days is limited, unless the phenomenon is sharply marked and has a period of exactly the number of days in question. An examination of some complicated cases brings out the difficulty of deciding when an apparent sequence is real. The conclusions reached will depend largely on the number of selected disturbed days per month, and the results may also be seriously affected by the possibly "accidental" occurrence of abnormally disturbed days.

C. R. Duvall.

Mialock, Urbano: *Determination of the radio-active content of the salts in the waters of the Atlantic and Pacific oceans between Montevideo and El Callao.*[1]

During a voyage from Montevideo to Callao the author collected various samples of sea water and evaporated them to dryness so as to obtain the dissolved salts. The radium contents of the salts were subequently determined by the usual method. The particular sample under examination was dissolved in distilled water which was then boiled; the emanation set free was drawn through an ionization chamber, where the saturation current which it was able to maintain was measured, the apparatus afterwards being standardized by a repetition of the experiment with a standard solution of a radium salt.

The following table represents the results obtained.

Longitude	Latitude	Distance from mainland	Grams of Radium in 1 gram of salt	Grams of Radium in 1 c.c. of Salt water
° ′	° ′	Miles		
59 53 E.	42 52 S.	157	72×10^{-14}	1224×10^{-17}
60 25 E.	43 30 S.	139	149	2371
60 55 E.	44 08 S.	135	135	2362
62 38 E.	46 16 S.	139	126	2142
63 40 E.	47 36 S.	83	36	587
64 13 E.	48 17 S.	62	9	292
67 06 E.	51 18 S.	69	56	1077
70 18 E.	52 43 S.	3	113	1474
76 22 E.	51 07 S.	40	98	1054
76 14 E.	46 07 S.	41	126	1726
74 30 E.	41 30 S.	25	300	4226
Corral		1	221	3542
Coronel		1	126	819
Sal. de Valparaiso		(in port	157	2746
Antofagasta		5	131	288
		3	599	5395
70 25 E.	21 17 S.	23	80	987
70 54 E.	18 05 S.	4	116	1215
Mollendo		3	200	3000
76 29 E.	14 10 S.	9	105	1130

[1] *Instituto Nacional del Profesorado Secundario; Communicaciones del Departamento de Física*, No. 3 (1915).

The mean value for all the observations is 147.7×10^{-14} grams of radium per gram of salt, or 1877.8×10^{-17} grams per c. c. of sea water. The value obtained by omitting observations taken in ports is 108.6×10^{-14} grams of radium per gram of salt.

It is recalled that J. Joly and Strutt obtained on the average 1.4 to 5×10^{-12} grams of radium per gram of rock for a large variety of rocks, and, according to Joly, the rocks of Simplón contain 6.1×10^{-12} grams of radium per gram of rock. W. F. G. SWANN.

SIMPSON, G. C.: *The Electricity of Atmospheric Precipitation.*[1]

After giving a statement of experimental results which are considered as having been substantiated by all recent observers, the author proceeds to discuss Elster and Geitel's "Influence Theory." This theory is based on the assumptions that small drops rebound from large drops without uniting with them, but that electrical contact takes place at the instant of rebound. It is supposed, in the theory, that the large drops which fall from the clouds have their under surfaces positively charged by the influence of the Earth's field, but that, by the act of overtaking and striking smaller drops during descent, they lose a portion of this charge and finally reach the Earth negatively charged.

Apart from criticisms which are raised against the fundamental assumptions of this theory and against the interpretation of the experiments on which these assumptions were based, it is maintained that the theory does not predict consequences in accordance with the facts. It is pointed out that the primary conclusion to which the theory leads is that the drops should arrive at the surface of the earth charged with electricity of the same sign as that on the portion of the surface on which they fall; a conclusion inconsistent with the known fact of the reversal of the potential-gradient during rain fall. The author claims, in fact, that the Elster and Geitel theory reverses cause and effect in making the charge on the rain a consequence of the electrical field rather than the field a consequence of the charge on the rain.

The author next develops the consequences of assuming that the origin of the charge on rain is to be sought in the "Breaking-Drop Theory." It is pointed out that, since the result of the breaking of the drops is to leave positive electricity on the drops and negative electricity in the atmosphere, the drops which have suffered disruption will fall to the Earth with a positive charge, and further, the normal potential-gradient will, by this action, become weakened and finally reversed. Both conclusions are in accordance with the facts.

It is possible for the air carrying its negative charge to get removed from the place of origin of the charge, and then precipitation formed in

[1] *Phil. Mag.*, S. 6, vol. XXX, p. 1 (1915).

it will start with a negative charge which may be carried to Earth. In this way it becomes possible to account for the occasional appearance of negatively charged rain.

A difficulty arises in the attempt to account for the breaking of the small drops concerned in non-thunderstorm rain, since drops of water of diameter smaller than 4 millimeters are not broken up spontaneously in falling through the air. The author, however, cites instances to show that very small drops do appear during gusts of wind, whatever may be the explanation of their origin, so that the only question which remains is that of whether the effect is sufficient. It is concluded that, in order to account for the facts in the case of non-thunderstorm rain, it is necessary to suppose that 0.1 of the total amount of the rain suffers disintegration into small drops.

During the quiet non-thunderstorm rainfall there is not so much breaking of drops as in thunderstorms, hence the charges measured are less. On the other hand the conditions are more suitable for the complete separation of the electricity, hence the ratio of positive to negative electricity is greater.

The known fact of the electrification of solid particles by their mutual impact in air is considered to be applicable to the impact of snow flakes, and from certain observations, it is concluded that the charge which becomes communicated to the snow in this way is positive, the corresponding negative charge appearing in the air. Assuming an ascending air current, the charged air will ascend as the snow descends, so that there will be an accumulation of negative electricity towards the top of the cloud. Snow formed here will start with a negative charge which, under suitable conditions, it might carry down to the ground; thus accounting for the negatively charged snow.

A list of papers dealing with the electricity of atmospheric precipitation is appended. W. F. G. S.

Schweidler, E. von, and K. F. W. Kohlrausch: *Atmosphärische Elektrizität.*[1]

The section on atmospheric electricity is divided into six subsections, of which the first two deal with the ionization of the atmosphere, the third with the electrical field of the atmosphere, the fourth with the atmospheric currents, the fifth with lightning discharge, and the sixth with theories of atmospheric electricity.

After commencing with a brief historical survey of the subject, the authors consider the methods of measurement, and the results obtained, for the electrical dissipation in the atmosphere, conductivity, ionic con-

[1]A section from volume 3 of "Handbuch der Elektrizität und des Magnetismus," edited by Prof. L. Graetz.

tent, and specific ionic velocity. The treatment, though concise, is rich with information, and is supported by a long list of references.

The authors next take up the discussion of the sources of ionization in the atmosphere—radio-active material in the Earth and atmosphere, penetrating radiation, etc. Here again will be found much information of value to anyone who is working in the subject.

The sub-section on the electrical field of the atmosphere comprises a description of the general features of the phenomena concerned, the methods of measurement, the annual and diurnal variations, the connection of the phenomena with the meteorological elements, and the variation of the electrical field and atmospheric charge-density with altitude.

The fourth sub-section, after dealing with the experimental methods and results for the measurement of the vertical conduction current, concerns itself with electrical convection currents, and with the earth-air currents resulting from aqueous precipitation.

The sub-section on lightning discharge gives a brief account of the various types of discharge observed, and it also includes a short account of polar lights.

The last sub-section after giving a revision of the conclusions reached earlier in connection with the explanation of the ionization of the atmosphere, discusses the theories which have been advanced by Elster and Geitel, Gerdien, C. T. R. Wilson, and Ebert, to account for the maintenance of the Earth's charge, and the article concludes with an account of the theories which have been put forward by C. T. R. Wilson, Gerdien, Simpson, and Elster and Geitel, to account for the electricity of atmospheric precipitation.

The whole subject is treated in a concise and lucid manner; the section is thoroughly up to date in respect of its material, the references are unusually copious in number, and the information supplied will be found particularly useful to anyone who is actually doing experimental work in the subject. If one were disposed to offer any criticism, it would probably be in regard to the absence of diagrams illustrating the instrumental appliances; this handicap will, however, not confuse a reader who has any familiarity with the apparatus. W. F. G. S.

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Photographed from Bossekop.

Photographed from Store Korsnes.

Aurora, March 22, 10^h 18^m 22^s, 1913.

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME XXI JUNE, 1916 NUMBER 2

PRELIMINARY REPORT ON THE RESULTS OF THE AURORA-BOREALIS EXPEDITION TO BOSSEKOP IN THE SPRING OF 1913. (FOURTH COMMUNICATION.)

BY CARL STÖRMER, *Kristiania.*

1. The three preceding communications on the results of my expedition to Bossekop in 1913 have been published in this Journal for September, 1913, and March and December[1], 1915. This fourth communication comprises the material accumulated March 16, 17, 18, 21, 22, 24, and 29, and consists of about 90 auroral photographs, obtained simultaneously from the stations Bossekop and Store Korsnes. As stated before, Store Korsnes is located about 27.5 km. to the north of Bossekop, and with this extensive base we obtained considerable parallaxes.

The altitudes measured—about 640 in number—present the same general features as before; this is indicated in Fig. 1.

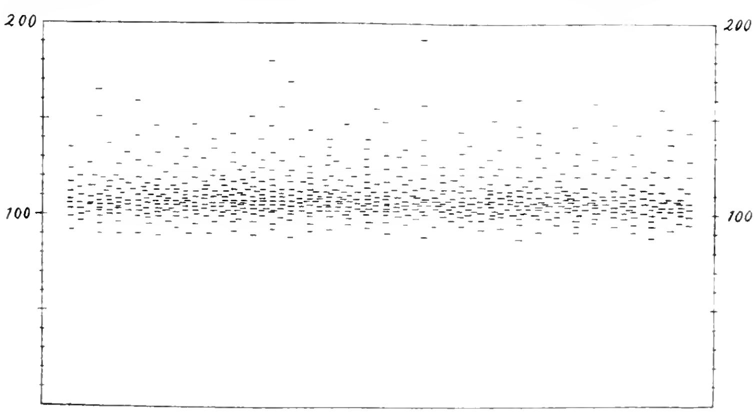


FIG. 1.

[1] In that number, Figs. 5 and 15 should be interchanged, and the lower figure on Pl. VI precede the upper. —S.

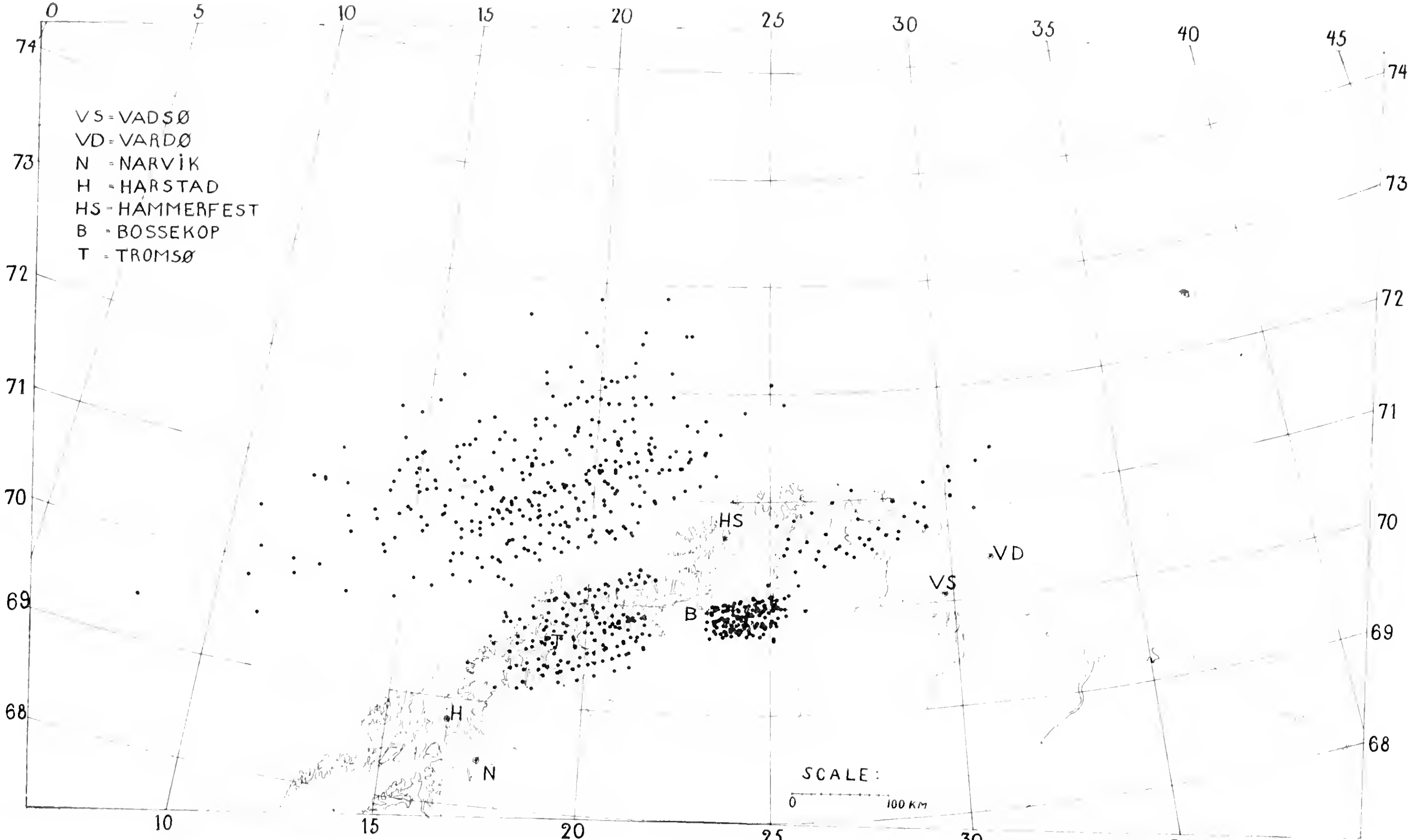

VS = VADSØ
VD = VARDØ
N = NARVIK
H = HARSTAD
HS = HAMMERFEST
B = BOSSEKOP
T = TROMSØ
HS
VD
VS
B
T
H
N
SCALE:
0
100 KM

FIG. 2.

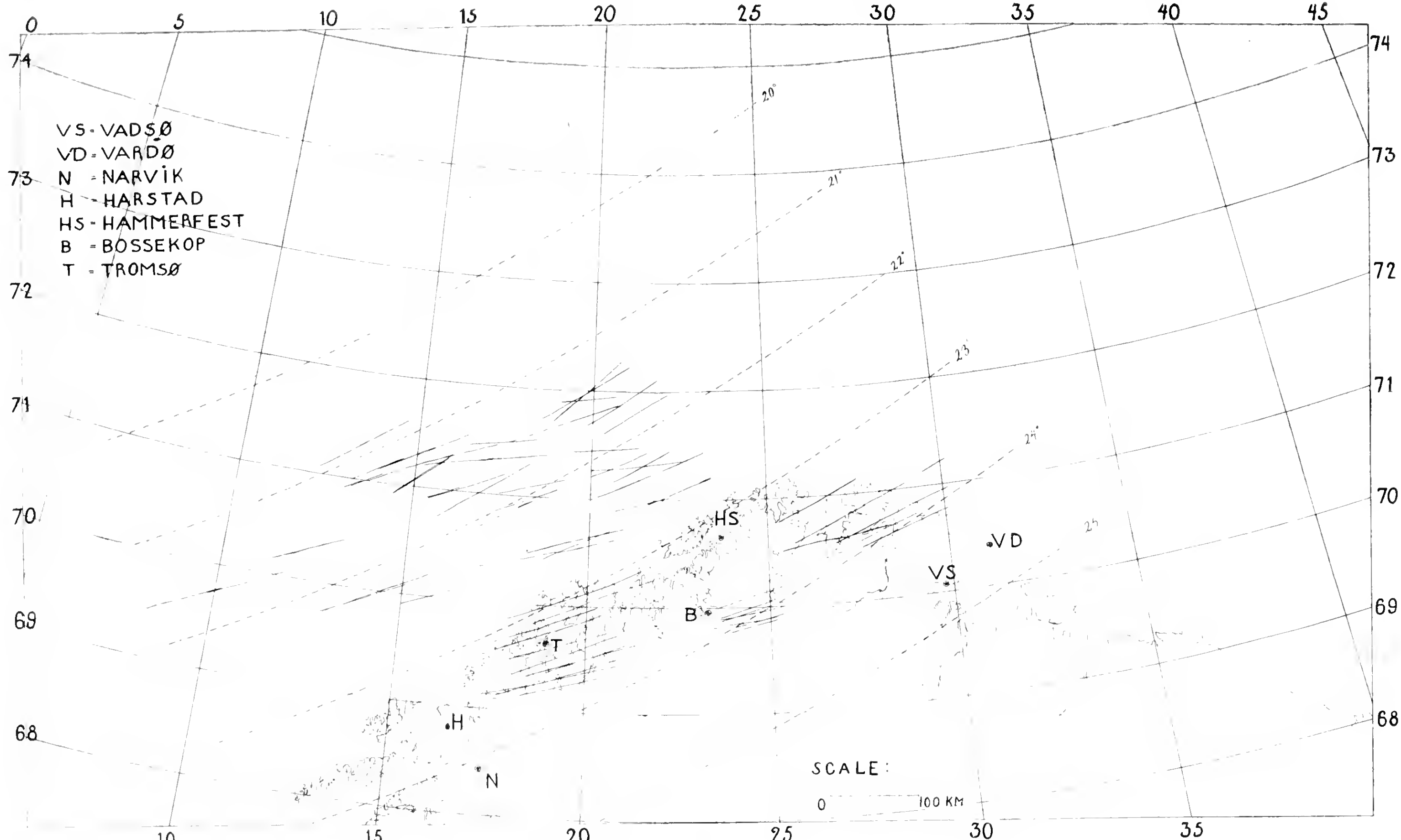

VS - VADSØ
VD - VARDØ
N - NARVIK
H - HARSTAD
HS - HAMMERFEST
B - BOSSEKOP
T - TROMSØ
HS
B
T
H
N
VD
VS
SCALE:
0
100 KM

FIG. 3.

There are accumulations here, also, especially near the altitudes of 102 and 107 km.; this is shown by the numbers at the different heights:

Altitude...	97	98	99	100	101	102	103	104	105	106	107	108	109
Number...	8	11	19	20	14	35	30	24	32	31	37	26	25

For each auroral point calculated, the corresponding point on the surface of the Earth, lying on the same Earth-radius, has been found. The distribution of these points is seen in Fig. 2.

There are two principal regions visible. The southern, stretching over land from Harstad to Vardo, is due mainly to auroral bands and curtains appearing on March 22, $9^{h}\ 50^{m}$ to $10^{h}\ 25^{m}$—Central European time reckoned from 0^{h} to 24^{h}, 0^{h} at noon—and March 29, $9^{h}\ 58^{m}$ to $10^{h}\ 15^{m}$.

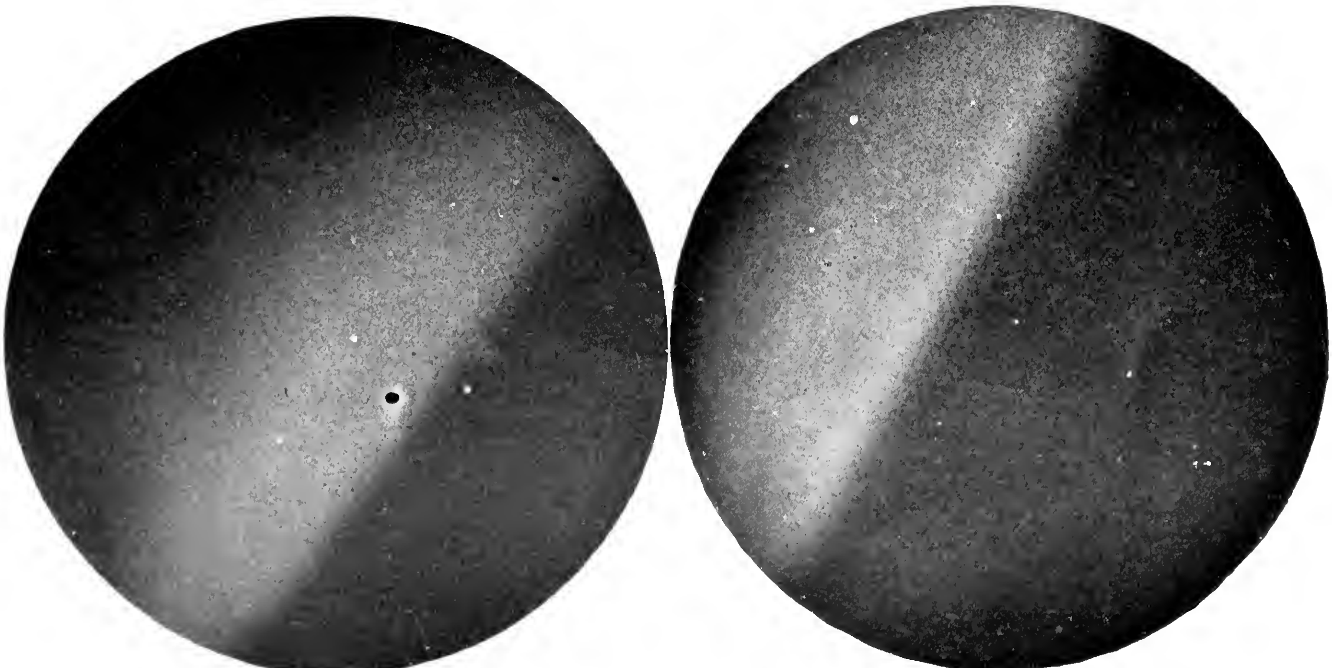
The accumulation of points just east of Bossekop is due to the auroral bands of March 29, of which we took about 15 successful photograms with the constellation of the Great Bear in the background.

The northern auroral region over the sea is for the most part due to faint and tranquil auroral arches from $12^{h}\ 45^{m}$ to $14^{h}\ 10^{m}$ on the night of March 29, 30.

In Fig. 3 the location of the principal auroral bands and arches is given. As was the case in the third communication, we have by means of dotted lines indicated circles with their centers on the magnetic axis of the Earth and passing through points whose angular distances from the intersection of this axis with the surface of the Earth are respectively 20°, 21°, 22°, 23°, 24°, and 25°.

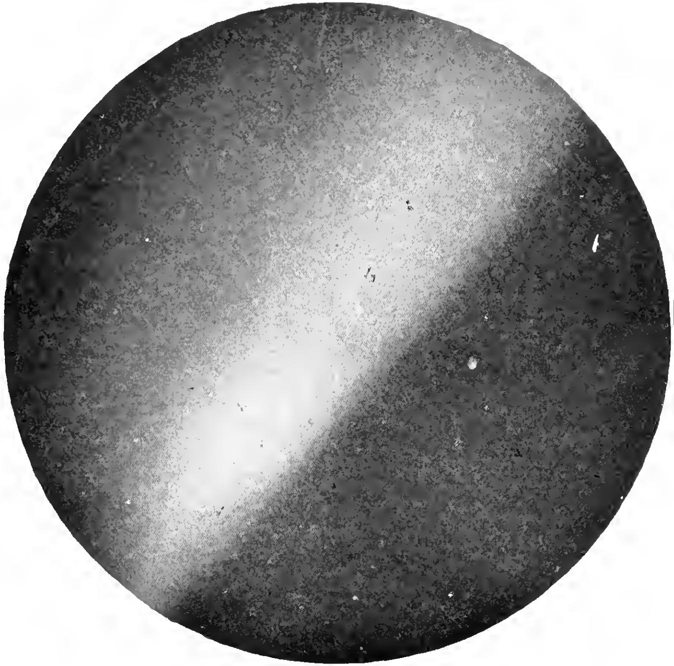
2. We are now going to describe some remarkable photograms of the auroral bands of March 22. The photograms show that the right border of the auroral band gradually descended in the atmosphere from about 130 km. at $9^{h}\ 56^{m}$ to about 120 km. at $10^{h}\ 18^{m}$; further, to about 105 km. at $10^{h}\ 20^{m}$, and finally the rays of the succeeding auroral curtain at $10^{h}\ 21^{m}$ came down to about 95 km. This development furnishes an interesting illustration of the theory I introduced in my memoirs "*Sur les trajectories des corpuscules électrisés dans l'espace sous l'action du magnétisme terrestre avec application aux aurores boréales, etc., I et II Archives des sciences physiques et Naturelles, Genève* 1907, 1911-12, especially of the section 26 of the concluding memoir.

The first photogram at $9^{h}\ 56^{m}$ is not reproduced here, because it is faint and lacking in precision. The next one, at $10^{h}\ 18^{m}\ 22^{s}$, is seen in Pl. II. Fig. 4 is a sketch of it.



Photographed from Bossekop. Photographed from Store Korsnes.

AURORA, MARCH 22, 10^{h} 19^{m} 12^{s}, 1913.



Photographed from Bossekop.

Photographed from Store Korsnes.

Aurora, March 22, 10ʰ 19ᵐ 38ˢ, 1913.

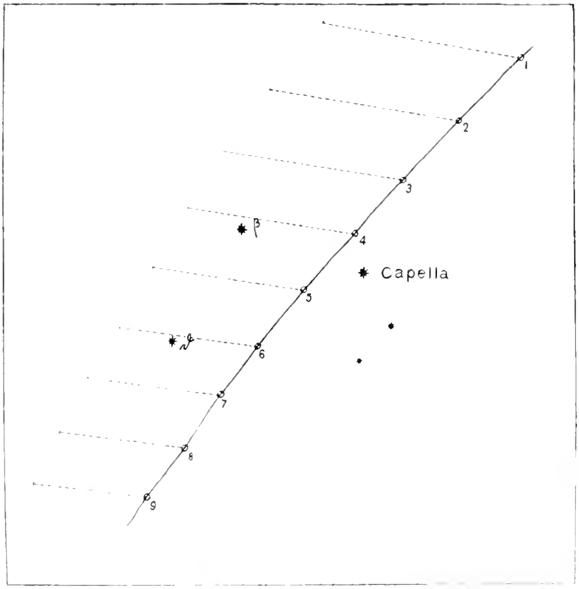


Fig. 4.

Along the right edge of the band there are chosen a series of points, and each point is connected by a dotted line with the corresponding position of the same point seen from Store Korsnes; the length of this line expressed in degrees is thus the parallax. The calculation gave the following altitudes in kilometers:

Number........	1	2	3	4	5	6	7	8	9
Altitude........	114	113	112	115	121	124	121	118	128

For the corresponding points on the Earth's surface see Fig. 8, I.

The next phase, at $10^h\ 19^m\ 12^s$, is seen in Pl. III (3 seconds exposure). Fig. 5 is a sketch of it. The altitudes in kilometers are:

Number........	1	2	3	4	5	6	7	8	9	10	11
Altitude........	109	110	108	107	108	107	105	103	102	103	100

The positions are indicated in Fig. 8 by II.

The next phase, at $10^h\ 19^m\ 38^s$, is seen in Pl. IV (3 seconds exposure). Here the arch has become very pronounced. Fig. 6 is the corresponding sketch. Here the altitudes in kilometers are:

Number....	1	2	3	4	5	6	7	8	9	10	11	12
Altitude....	104	105	106	108	106	108	107	105	102	102	103	102

The positions are indicated in Fig. 8 by III.

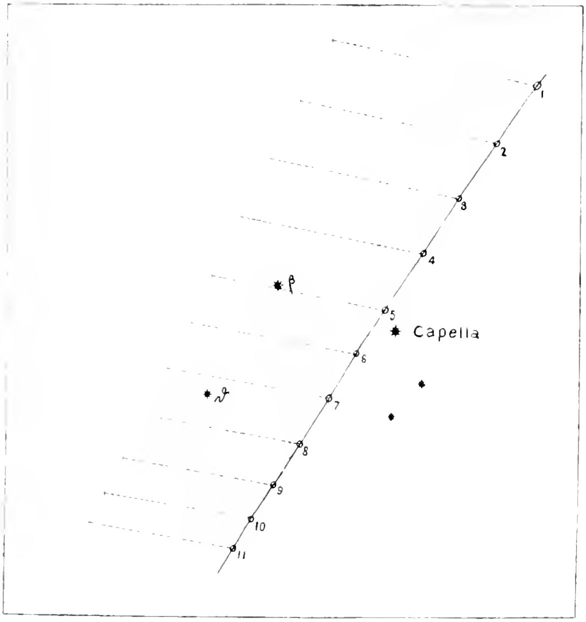


FIG. 5.

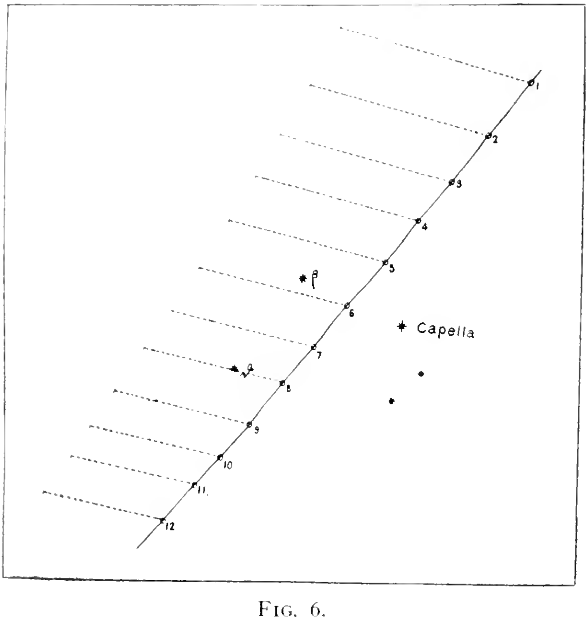
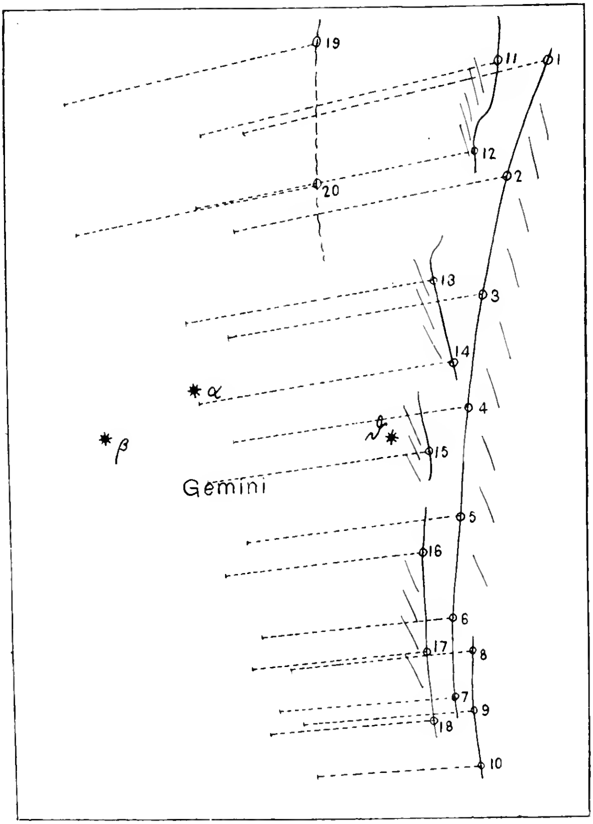


FIG. 6.


19
11
1
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20
13
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α
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10

Fig. 7.

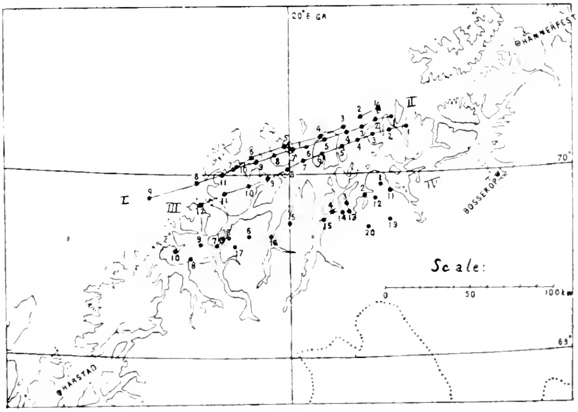

20° E Gr
HAMMERFEST
II
70°
I
III
IV
BOSSEKOP
Scale:
0
50
100
69°
HARSTAD

Fig. 8.

After this the auroral curtain appeared as seen in Pl. V, giving the photogram at 10 h 20 m 35 s (3.5 to 4.5 seconds exposure). The altitudes in kilometers are given in the following table (see Fig. 7):

Number...	1	2	3	4	5	6	7	8	9	10
Altitude...	108	104	101	100	100	103	103	107	106	107
Number...	11	12	13	14	15	16	17	18	19	20
Altitude...	101	101	103	94	102	104	104	109	114	109

As seen in Fig. 8, position IV, the curtain is situated south of the arch in the preceding photograms.

At 10 h 21 m 8 s a photogram was taken of the same curtain, but it is not reproduced here. It gave distinct rays downwards to about 97 km. Shortly afterward it disappeared, and in the next photogram, at 10 h 21 m 50 s, no rays are seen.

3. We shall now give some interesting photograms of March 29. The first one, with the Great Bear in the background, at 10 h 13 m 43 s, is seen in Pl. VI, and is the fourteenth one of a series of successful photograms of auroral arches through the zenith from southwest to northeast. Fig. 9 is a sketch of it. The altitudes in kilometers are:

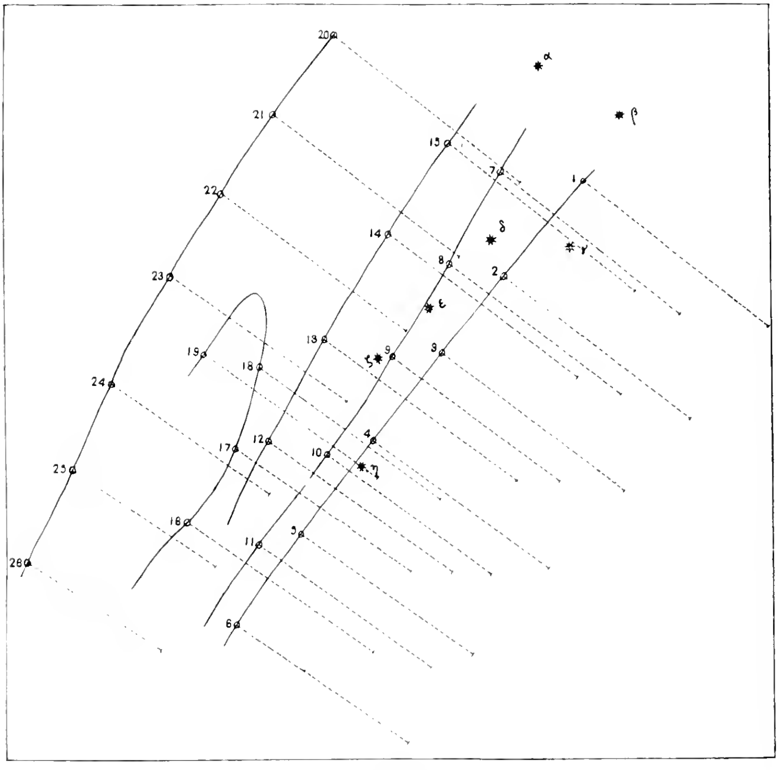
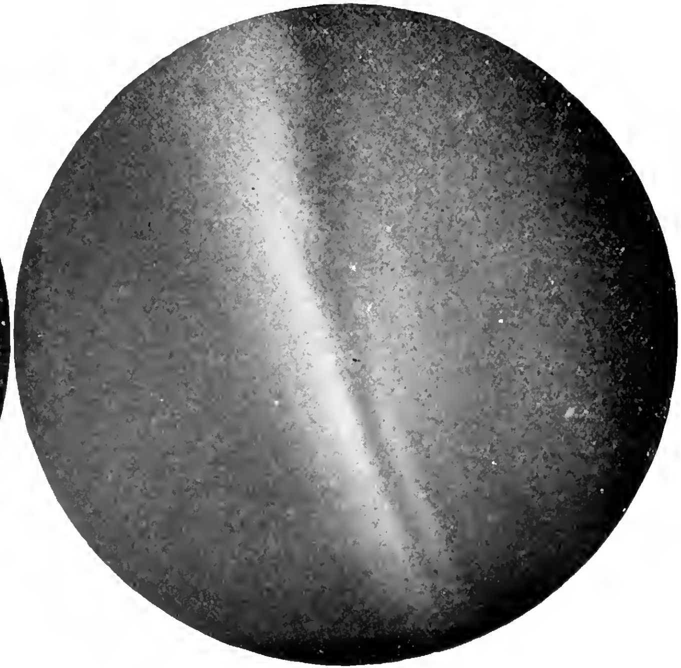


FIG. 9.

Photographed from Bossekop.



Photographed from Store Korsnes.

AURORA, MARCH 22, 10^{h} 20^{m} 35^{s}, 1913.

Photographed from Store Korsnes.

Photographed from Bossekop.

AURORA, MARCH 29, $10^h\ 13^m\ 43^s$, 1913.

Number.....	1	2	3	4	5	6	7	8	9	10	11	12	13
Altitude.....	110	104	103	104	103	102	112	113	113	110	102	100	100
Number.....	14	15	16	17	18	19	20	21	22	23	24	25	26
Altitude.....	106	110	96	105	105	110	113	112	109	113	120	130	134

In Fig. 10 are seen the corresponding points on the Earth's surface.

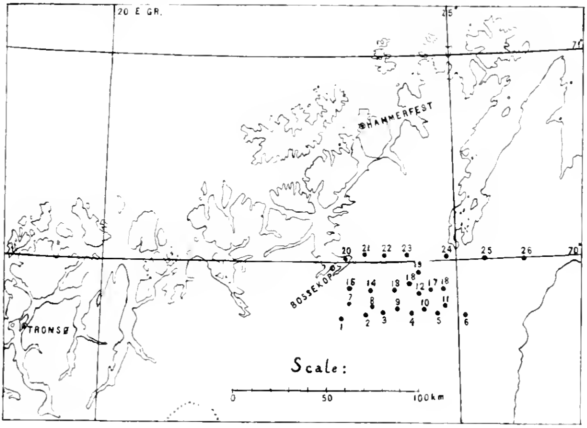


FIG. 10.

The next photogram of the same aurora, at $10^h\ 14^m\ 6^s$, is seen in Pl. VII, with corresponding sketch in Fig. 11. The altitudes are:

Number...	1	2	3	4	5	6	7	8	9	10
Altitude...	100	105	105	104	104	102	103	106	102	108
Number...	11	12	13	14	15	16	17	18	19	20
Altitude...	108	110	113	105	110	112	107	120	118	118

The positions are not much different from those of the foregoing aurora, as seen in Fig. 12.

During the following ten minutes the auroral bands gained in intensity and moved northward. Of the four successful photograms of this period we have reproduced one in Pl. VIII, showing the aurora in the northwest at $10^h\ 24^m$. The points in the corresponding sketch, Fig. 13, give the following altitudes in kilometers:

Number.....	1	2	3	4	5	6	7	8
Altitude.....	110	107	110	113	107	107	104	98

In Fig. 14 are seen the corresponding positions.

The subsequent development showed increased intensity. A photogram is seem in Pl. IX, at $10^h\ 25^m\ 43^s$, with Cassiopeia in the background. For sketch see Fig. 15. The altitudes are:

Number.....	1	2	3	4	5	6
Altitude.....	102	101	102	106	105	110

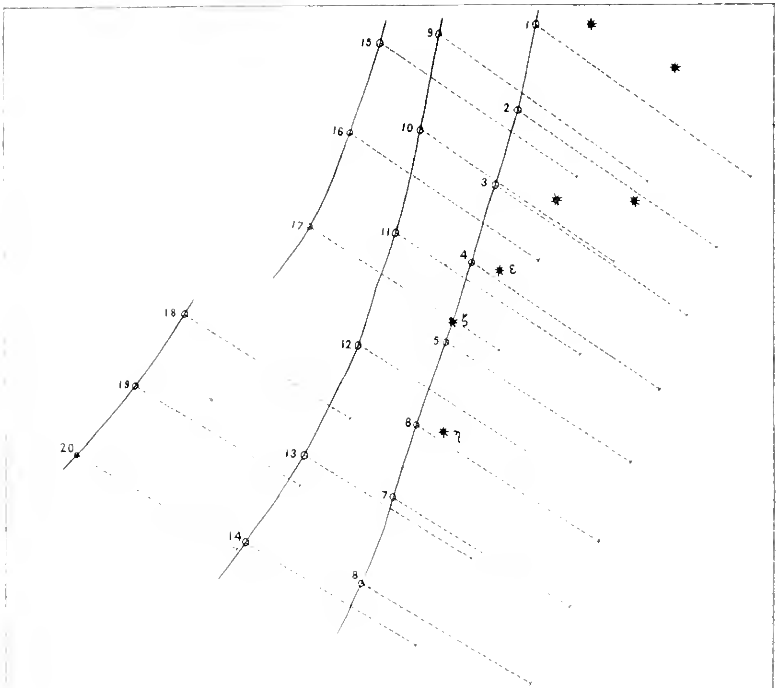

1
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FIG. 11.

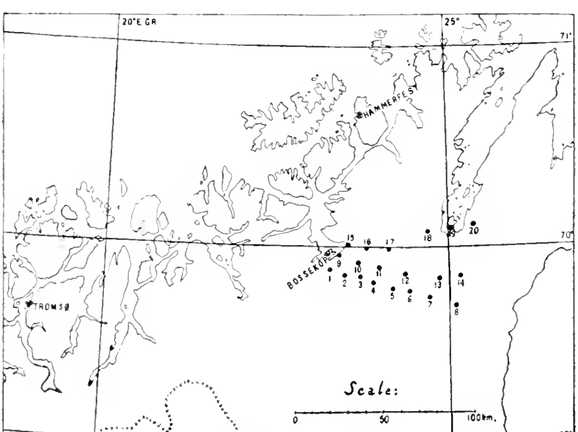
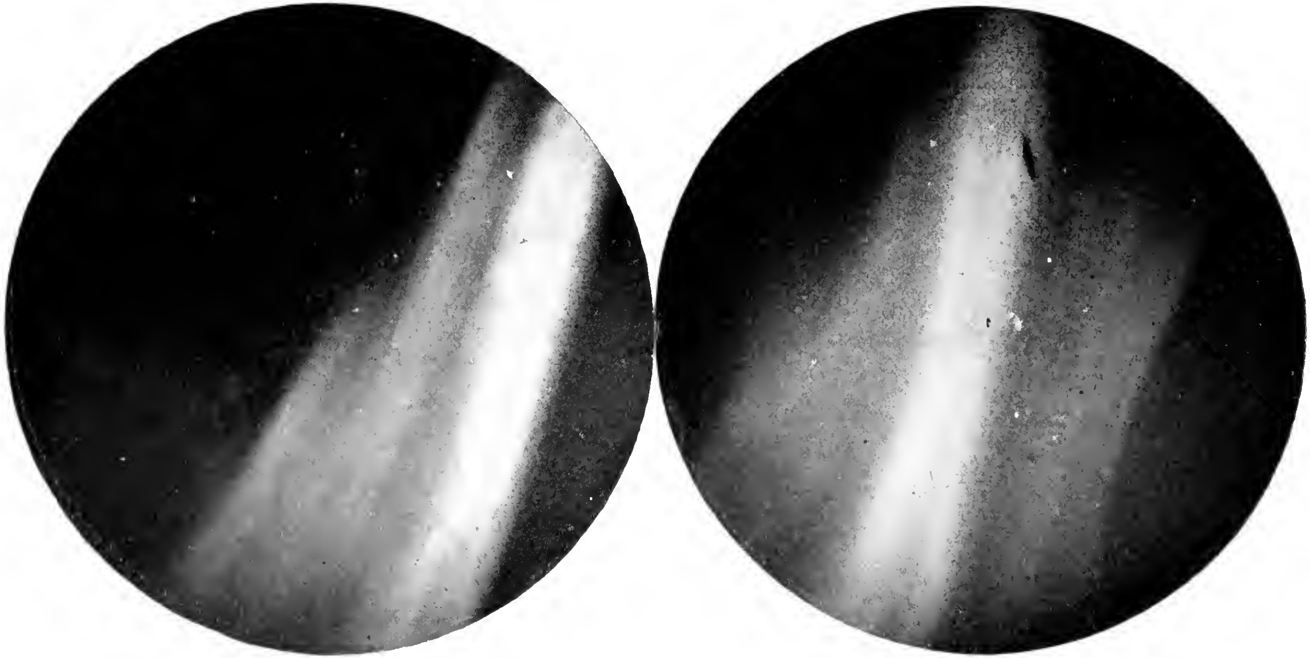
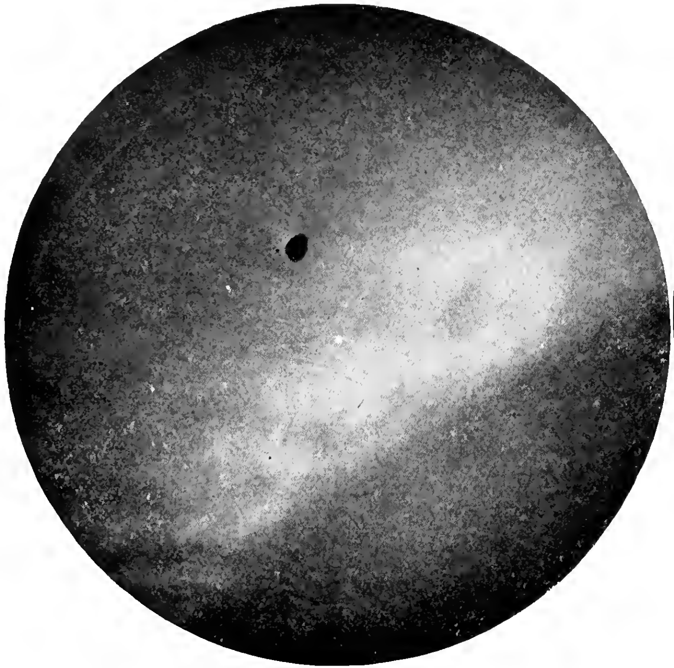

20° E GR
25°
71°
70°
69°
HAMMERFEST
BOSSEKOP
TROMSØ
Scale:
0
50
100km.

FIG. 12.

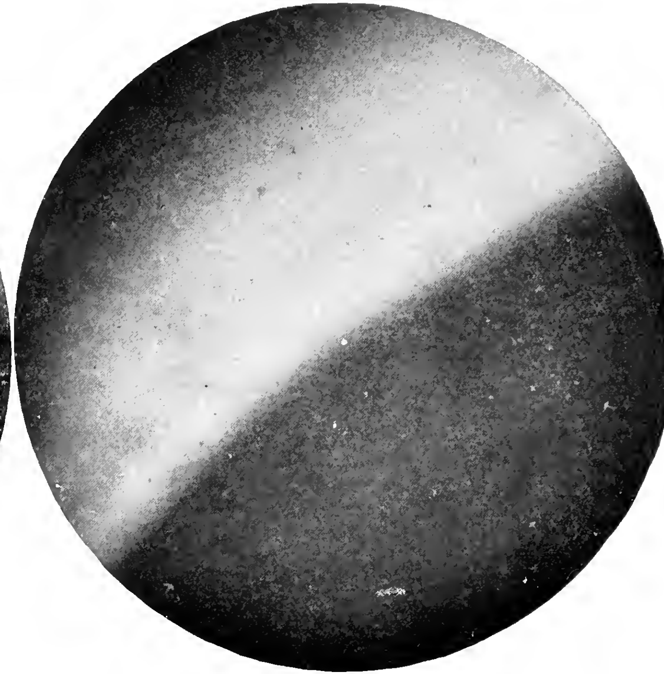


Photographed from Store Korsnes. Photographed from Bossekop.

Aurora, March 29, $10^h\ 14^m\ 06^s$, 1913.



Photographed from Bossekop.



Photographed from Store Korsnes.

AURORA, MARCH 29, 10^{h} 24^{m}, 1913.

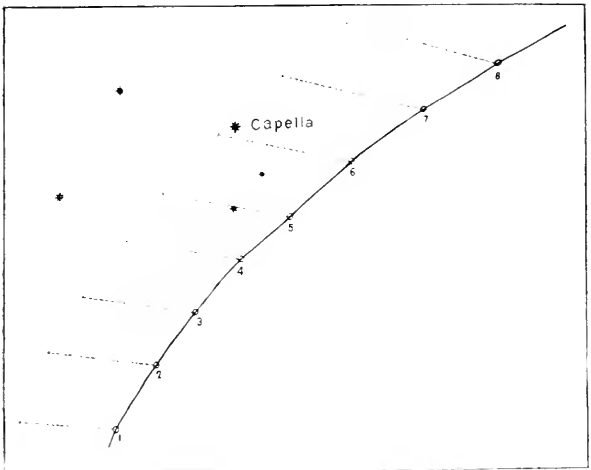


Fig. 13.

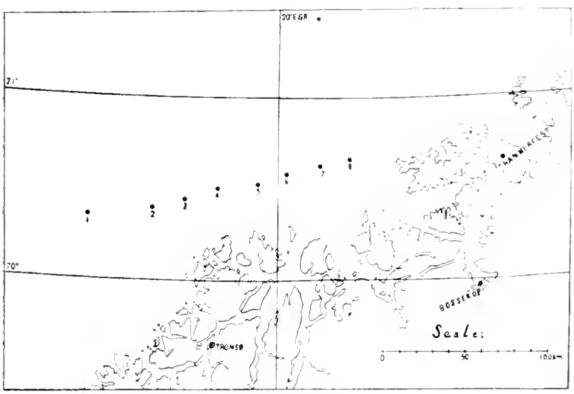


Fig. 14.

The corresponding positions are shown in Fig. 16.

The last photogram here given is seen in Pl. X. It represents an auroral curtain at $11^{h}\ 31^{m}$; see Fig. 17. The altitudes are:

Number........	1	2	3	4	5	6	7	8	9
Altitude........	107	100	99	97	93	96	102	118	130

Points 8 and 9 were chosen on a ray caused by a fold in the curtain. This ray was so situated that we looked tangentially at the curtain, which enhanced the feeble light in the upper part of the curtain. The positions can be seen in Fig. 18. We have here the characteristic convexity toward the south, shown by many examples of auroral curtains, especially when they are developing eastward along an auroral arch.

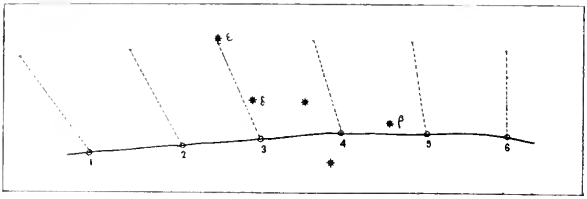


FIG. 15.

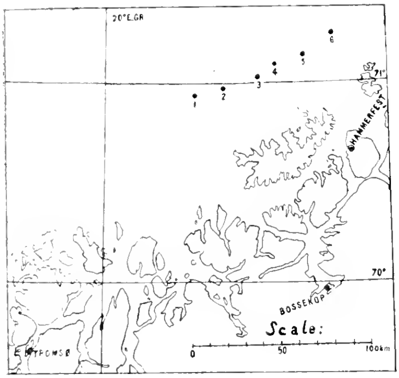


FIG. 16.

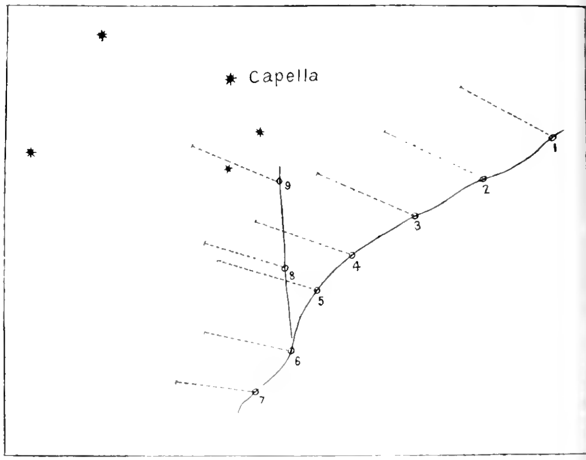


FIG. 17.

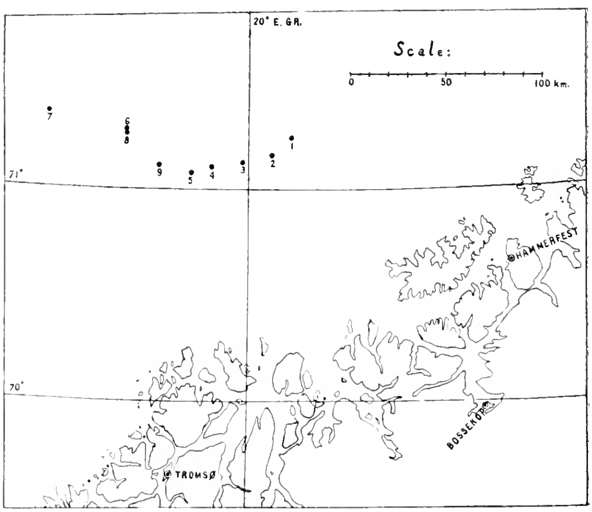
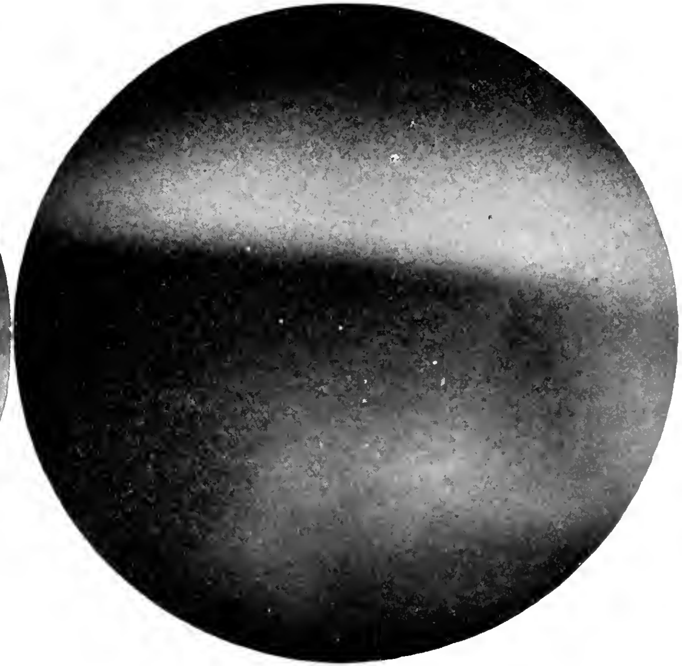


FIG. 18.

Photographed from Bossekop.



Photographed from Store Korsnes.

AURORA, MARCH 29, $10^h\ 25^m\ 43^s$, 1913.

Photographed from Bossekop.

Photographed from Store Korsnes.

AURORA, MARCH 29, 11^h 31^m, 1913.

ON THE RESULTS OF SOME MAGNETIC OBSERVATIONS DURING THE SOLAR ECLIPSE OF AUGUST 21, 1914.

By L. A. Bauer and H. W. Fisk.

No definite information having been received by the Department of Terrestrial Magnetism up to June, 1914, that an organized effort would be made to secure magnetic, electric, and allied observations during the solar eclipse of August 21, 1914, the belt of totality of which (Figs. 1 and 2) was favorably located for European observatories, it was decided to stimulate interest in the important event. Accordingly, the circular letter of June 23, 1914, on page 58, was sent to a number of persons and institutions and published in *Nature* (July 16, 1914, p. 507) and in *Science* (July 24, 1914, p. 140). Later it was ascertained that others, notably Dr. V. Carlheim-Gyllensköld[1] had succeeded in likewise inaugurating desired observational work. It thus happened that at some of the contributing observatories observations were made both in accordance with his program and with ours. Naturally, the following preliminary report deals only with the data obtained in response to our own request. Unfortunately, owing to the European war, the desired data have not yet been received from all observatories which had promised their aid. The majority of the communications here published, it is gratifying to state, were received within six months after the date of the eclipse. It was thought desirable not to await the arrival of further material, but, instead, to make what we have accessible to those who can undertake a more exhaustive discussion. Grateful acknowledgement is here made to all who have cooperated for their cordial and prompt responses.

Abstracts are given of the various reports received, excepting those which have already been published in this journal.[2] It will be observed that we have given, in general, only the five-minute mean results, although usually the results were tabulated for every minute in the original report. For example, the result published opposite the time $10^h\ 05^m$ is the mean of the five readings from $10^h\ 03^m$ to $10^h\ 07^m$, etc. Generally also copies of the photographic traces were received, but no attempt was made to scale them if other data (eye readings or magnetogram scalings) were supplied.

[1] Sur une cause possible de l'influence des éclipses de soleil sur le magnétisme terrestre, *Ark. Matem. Stockholm*, Bd. 10, No. 9, 1914.

[2] See Chree's report on the Kew observations, vol. 20, pp. 71-74, 1915; also Hazard's report on the observations at the United States Magnetic Observatories, vol. 21, pp. 9-14, 1916.

To obtain, in as widely-distributed regions of the Earth as possible, some idea of its magnetic state during the eclipse, the field observers of the Department of Terrestrial Magnetism were instructed to make special declination observations, if circumstances permitted. There were thus obtained the five series of observations given in Tables 19-23, distributed over the Earth from Labrador to the Congo, and from the District of Columbia to China.

Effective assistance was rendered in the computations, drawing of the diagrams, and in the preparation of the reports for publication by Messrs. W. F. Wallis, C. R. Duvall, R. R. Mills, and H. D. Harradon, all of the Department of Terrestrial Magnetism.

Proposed International Magnetic and Allied Observations During the Total Solar Eclipse of August 21, 1914 (Civil Date).

In response to an appeal for simultaneous magnetic and allied observations during the coming total solar eclipse, cooperative work will be conducted at stations along the belt of totality in various countries and also at some outside stations. The general scheme of work proposed embraces the following:

1. Simultaneous magnetic observations of any or all of the elements according to the instruments at the observer's disposal, every minute from August 21, 1914, 10^h A. M. to 3^h P. M. Greenwich civil mean time, or from August 20, 22^h to August 21, 3^h Greenwich astronomical mean time.

(To insure the highest degree of accuracy, the observer should begin work early enough to have everything in complete readiness in proper time. See precautions taken in previous eclipse work as described in the journal TERRESTRIAL MAGNETISM, vol. 5, p. 146, and vol. 7, p. 16. *Past experience has shown it to be essential that the same observer make the readings throughout.*)

2. At magnetic observatories, all necessary precautions should be taken to insure that the self-recording instruments will be in good operation not only during the proposed interval but also for some time before and after, and eye-readings should be taken in addition wherever it is possible and convenient. (*It is recommended that, in general, the magnetograph be run on the usual speed throughout the interval, and that, if a change in recording speed be made, every precaution possible be taken to guard against instrumental changes likely to affect the continuity of the base line.*)

3. Atmospheric-electric observations should be made to the extent possible with the observer's equipment and personnel at his disposal.

4. Meteorological observations in accordance with the observer's equipment should be made at convenient periods (as short as possible) throughout the interval. It is suggested that, at least, temperature be read every fifth minute (directly after the magnetic reading for that minute).

5. Observers in the belt of totality are requested to take the magnetic reading every thirty seconds during the interval, 10 minutes before and 10 minutes after the time of totality, and to read temperature also every thirty seconds, between the magnetic readings.

It is hoped that full reports will be forwarded as soon as possible for publication in the journal of TERRESTRIAL MAGNETISM.

Washington, D. C., June 23, 1914. L. A. BAUER.

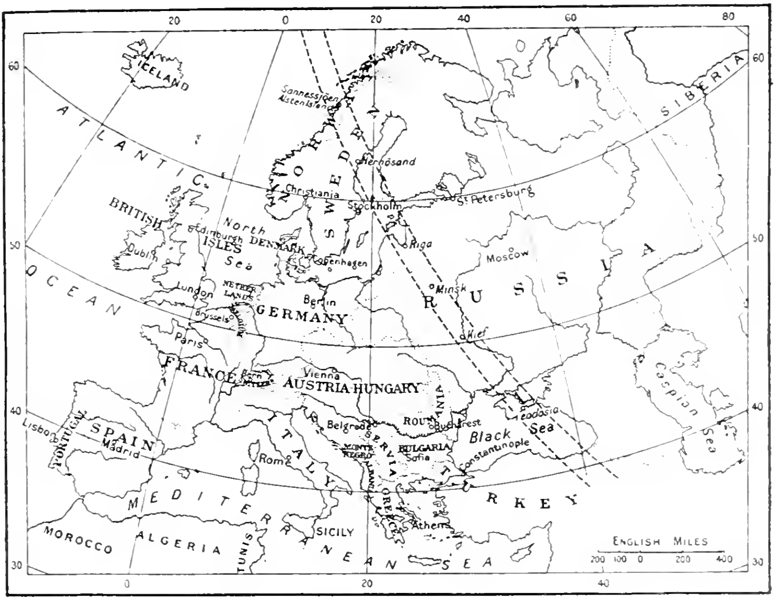


FIG. 1.—Map showing Belt of Totality for Solar Eclipse of August 21, 1914.

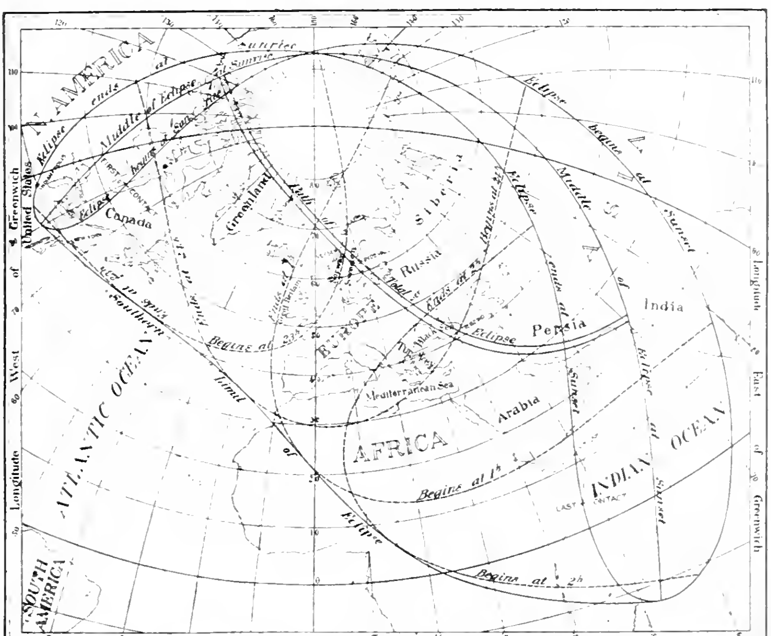


FIG. 2.—Map showing Region of Visibility of the Solar Eclipse of Aug. 21, 1914.

No. 1.—Observations at the Eskdalemuir Observatory, Scotland.

The magnetic results given in Table 1-A were derived from the final values for the three intensity components communicated by Superintendent L. F. Richardson. The values of the declination and of the horizontal intensity were computed in the Department of Terrestrial Magnetism from the furnished values of the two rectangular components (north and west). The sensitivities in γ per mm. for the magnetograms were: 8.8 (N. Comp.); 8.7 (W. Comp.); 3.9 (Vert. Comp.).

Table 1-A.—*Results of magnetic observations at the Eskdalemuir Observatory on August 21, 1914.*

G.M.T.	Intensity N. Comp.	Intensity W. Comp.	Intensity V. Comp.	Hor'l	Decl'n (West)
h m	γ	γ	γ	γ	° ′
10 01	15976	5109	45192	16773	17 44.0
05	15971	08	92	768	44.2
10	15971	10	92	768	44.5
15	15973	14	92	771	45.2
20	15975	17	92	775	45.7
25	15975	19	92	775	46.0
30	15974	18	92	774	46.0
35	15972	16	92	771	45.6
40	15974	16	92	773	45.5
45	15975	16	92	774	45.6
50	15978	19	92	778	45.8
55	15982	22	90	783	46.3
11 00	15985	25	89	786	46.6
05	15986	26	89	788	46.6
10	15986	27	89	788	46.9
15	15988	28	88	790	47.0
20	15989	28	88	791	46.9
25	15989	29	86	792	47.1
30	15990	30	86	793	47.3
35	15989	30	85	792	47.3
40	15990	31	84	793	47.4
45	15991	32	84	793	47.5
50	15992	31	84	795	47.3
55	15990	30	84	793	47.3
12 00	15989	30	84	792	47.3
05	15989	30	85	792	47.3
10	15987	30	86	790	47.4
15	15990	35	86	795	48.2
20	15993	38	87	798	48.6
25	15994	40	88	800	49.0
30	15995	41	88	801	49.1
35	15996	43	88	802	49.4
40	15995	44	88	802	49.7
45	15994	44	88	801	49.6
50	15991	43	88	798	49.8
55	15992	43	89	798	49.7

G.M.T.	Intensity N. Comp.	Intensity W. Comp.	Intensity V. Comp.	Hor'l	Decl'n (West)
h m	γ	γ	γ	γ	° ′
13 00	15990	5145	45189	16798	17 50.1
05	15993	45	89	800	50.0
10	15993	45	89	800	50.0
15	15993	46	90	801	50.1
20	15990	44	91	797	49.9
25	15989	43	92	796	49.8
30	15987	42	92	794	49.8
35	15988	43	93	795	49.9
40	15988	42	94	795	49.6
45	15990	44	94	797	50.0
50	15992	45	94	799	50.0
55	15992	46	95	800	50.1
14 00	15994	48	96	802	50.5
05	15994	47	96	802	50.4
10	15994	45	96	801	50.0
15	15996	47	96	804	50.3
20	15998	47	96	805	50.1
25	15996	46	96	804	50.0
30	15998	45	96	805	49.7
35	16000	44	96	807	49.4
40	16001	43	96	807	49.1
45	16000	42	96	806	49.1
50	16003	41	96	808	48.7
55	16004	41	96	810	48.5
14 59	16004	39	96	809	48.1

G. M. T. Mean hourly values.

G.M.T.	Intensity N. Comp.	Intensity W. Comp.	Intensity V. Comp.	Hor'l	Decl'n (West)
h	γ	γ	γ	γ	° ′
10	15979	5112	45192	16777	17 44.4
11	15983	123	90	784	46.3
Noon	15989	34	86	793	48.1
13	15992	44	89	799	49.9
14	15994	46	96	802	50.1
15	16004	39	97	809	48.1

TABLE 1-B.—*Air temperatures at the Eskdalemuir Observatory during the solar eclipse of August 21, 1914.*

G.M.T.	Abs. Temp.	G.M.T.	Abs. Temp.	G.M.T.	Abs. Temp.	G.M.T.	Abs. Temp.	G.M.T.	Abs. Temp.
h m	°	h m	°	h m	°	h m	°	h m	°
10 00	287.7	11 00	288.7	12 00	289.0	13 00	288.8	14 00	288.2
10	287.8	10	288.8	10	288.6	10	288.7	10	288.2 [a]
20	287.7	20	288.7	20	288.5	20	288.8	20	288.4
30	287.7	30	288.6	30	288.5	30	289.0	30	288.5
40	288.0	40	288.7	40	288.6	40	288.6	40	288.6
50	288.3	50	288.6	50	289.0	50	288.4	50	289.0
								15 00	289.4

[a] Minimum, 288.°1 at 14^h 05^m.

TABLE 1-C.—*Hourly values of temperature recorded at the Eskdalemuir Observatory on August 21, 1914, and converted into centigrade degrees, absolute.*

G. M. T.	Abs. Temp.	G. M. T.	Abs. Temp.	G. M. T.	Abs. Temp.	G. M. T.	Abs. Temp.
h	°	h	°	h	°	h	°
1	281.9	7	283.6	13	288.8	19	286.9
2	282.7	8	285.2	14	288.2	20	286.1
3	282.9	9	286.4	15	289.2	21	286.1
4	281.4	10	287.6	16	288.6	22	286.3
5	281.6	11	288.6	17	287.5	23	285.7
6	282.8	Noon	288.8	18	287.6	Midnight	284.7

Maximum, 289.°4 at 15^h 05^m; Minimum, 281.°3 at 4^h 45^m.

ATMOSPHERIC-ELECTRIC OBSERVATIONS AT THE ESKDALEMUIR OBSERVATORY, AUGUST 20-22, 1914.

(*Abstract of L. F. Richardson's Report.*)

Ionization and conductivity were determined by eye observations made at every hour G. M. T. (civil) from 4^h to 20^h on the three days August 20, 21, and 22, 1914. On the 21st, additional observations were made at the half-hours from 10^h 30^m to 19^h 30^m. The results are given in Tables 1-D and 1-E. The positive and nega-

tive charges in the air per c. c. (E_+ and E_-, respectively) were obtained from two Ebert aspiration-apparatuses made by Messrs. Günther and Tegetmeyer, and the durations of the individual runs were from 12 to 15 minutes.

The conductivity was determined with a Wilson "universal portable electrometer" made by the Cambridge Scientific Instrument Company. The electrometer was allowed to collect ions for three successive periods of five minutes, and a quantity proportional to the potential-gradient was observed at the beginning and end of each period by the same apparatus. All measurements were made by observing the gold-leaf with the compensator drawn fully out and with the cap on. The compensator was used to adjust the collector to earth-potential during the collecting period. If δ_1 is the displacement of the gold-leaf due to the charge induced on the plate by the potential-gradient at the beginning of the five minutes, and δ_3 a similar quantity at the end of the same period, and if δ_2 is the displacement of the leaf due to the ions collected during five minutes while at earth-potential, then it was assumed that the conductivity λ in E. M. U. is:

$$\lambda = \frac{\delta_2}{2\pi v^2 t\,(\delta_1 + \delta_3)}$$

where t is the time of exposure in seconds and v the velocity of light.

The potential-gradient observations, made in the open, are given in Tables 1-D and 1-E, expressed in volts per meter. The air-earth currents i, as recorded in the tables, were calculated from λ and the potential-gradient by Dr. W. F. G. Swann of the Department of Terrestrial Magnetism. Copies of the electrograms from the Kelvin water-dropper and of the thermograms were also supplied.

Cloud Observations were made hourly from 4^h to 21^h. It may suffice to say that the sky was completely or 0.9 covered up to 16^h, and that from then onwards the amount of cloud decreased a little. The motion of the clouds was in general from the SW.

Condition of the upper air. Two registering balloons were liberated so as to reach their highest points one before and one after the maximum obscuration. If the instruments are found, the results will appear in the Geophysical Journal published by the Meteorological Office, London.

Observations with the Ebert and Wilson instruments were made from 4^h to 20^h by Mr. E. H. Nichols on a number of days in August, and will be published in due course. [See p. 79.]

TABLE 1-D.—*Results of atmospheric-electric observations at Eskdalemuir Observatory on August 20 and 21, 1914.*[a]

G. M. T.	August 20 λ (E.M.U. ×10⁻²⁵)	August 20 E− (E. M. U. × 10⁻²⁰)	August 20 E+ (E. M. U. × 10⁻²⁰)	August 20 Av. E (E. M. U. × 10⁻²⁰)	August 20 E+/E−	August 20 P. G. (V/m)	August 20 i (E.M.U. ×10⁻¹⁷)	August 21 λ (E.M.U. ×10⁻²⁵)	August 21 E− (E. M. U. × 10⁻²⁰)	August 21 E+ (E. M. U. × 10⁻²⁰)	August 21 Av. E (E. M. U. × 10⁻²⁰)	August 21 E+/E−	August 21 P. G. (V/m)	August 21 i (E.M.U. ×10⁻¹⁷)
h m														
4 00	474	247	688	468	2.78	290	1.37	.212	[40]	[140]	[90]	[3.50]	870	1.84
5 00	577	55	239	147	4.35	320	1.85	[.335]	[80]	[230]	[155]	2.88	830	2.78
6 00	[510]	96	478	287	4.98	390	1.99	.457	137	239	188	1.74	590	2.70
7 00	442	137	777	457	5.68	390	1.72	[.500]	[110]	419	265	3.80	330	1.65
8 00	[710]	260	389	325	1.50	160	1.14	[.543]	82	419	250	5.11	340	1.85
9 00	971	192	419	306	2.18	110	1.07	.583	69	419	244	6.08	270	1.57
10 00	789	137	448	293	3.26	150	1.18	.856	110	508	309	4.62	150	1.28
10 30	...	...	...	...	...	...	...	.771	192	628	410	3.26	160	1.23
11 00	.631	110	359	235	3.26	170	1.07	.724	178	239	209	1.34	140	1.01
11 30	...	...	...	...	...	...	...	.710	192	239	216	1.72	130	0.92
12 00	.642	247	269	258	1.09	180	1.16	.817	219	389	304	1.78	110	0.90
12 30	...	...	...	...	...	...	...	.730	206	269	238	1.31	110	0.80
13 00	.853	384	419	402	1.09	140	1.19	.938	247	389	318	1.57	130	1.22
13 30	...	...	...	...	...	...	...	.847	233	359	296	1.54	160	1.36
14 00	.775	233	389	311	1.67	150	1.16	.539	247	568	408	2.30	130	0.70
14 30	...	...	...	...	...	...	...	1.406	329	508	419	1.55	120	1.69
15 00	.730	137	299	218	2.21	150	1.10	1.208	247	568	408	2.30	130	1.57
15 30	...	...	...	...	...	...	...	1.096	217	628	438	2.54	130	1.42
16 00	.574	192	448	320	2.33	160	0.92	.817	384	807	596	2.10	130	1.06
16 30	...	...	...	...	...	...	...	.897	507	1286	897	2.55	150	1.35
17 00	.555	123	269	196	2.19	160	0.89	1.821	548	1226	887	2.24	170	3.10
17 30	...	...	...	...	...	...	...	1.824	491	1226	860	2.49	130	2.37
18 00	.582	110	478	294	4.35	180	1.05	1.872	180	1166	823	2.43	170	3.18
18 30	...	...	...	...	...	...	...	1.762	274	1226	750	4.49	180	3.17
19 00	.152	123	329	226	2.67	260	1.38	1.580	178	1076	627	6.04	250	3.95
19 30	...	...	...	...	...	...	...	1.480	164	927	546	5.65	350	5.18
20 00	.213	55	269	162	4.90	310	0.66	1.366	82	897	490	10.94	440	6.01
20 30										...	...	...	...	...

[a] Bracketed figures refer to interpolated or extrapolated results.

TABLE 1-E.—*Results of atmospheric-electric observations at Eskdalemuir Observatory on August 21 and 22, 1914.*[a]

G. M. T.	August 21[b] λ (E.M.U. $\times 10^{-25}$)	E_- (E. M. U. $\times 10^{-20}$)	E_+ (E. M. U. $\times 10^{-20}$)	Av. E (E. M. U. $\times 10^{-20}$)	$\frac{E_+}{E_-}$	i (E.M.U. $\times 10^{-17}$)	August 22 λ (E.M.U. $\times 10^{-25}$)	E_- (E. M. U. $\times 10^{-20}$)	E_+ (E. M. U. $\times 10^{-20}$)	Av. E (E. M. U. $\times 10^{-20}$)	$\frac{E_+}{E_-}$	P. G. (V./m)	i (E.M.U. $\times 10^{-17}$)
h m													
4 00	.212	40	140	90	3.50	1.84	.350	233	897	565	3.85	320	1.12
5 00	[.335]	86	203	145	2.36	2.78	.226	247	867	557	3.51	440	0.99
6 00	.431	109	296	203	2.72	2.54	.434	151	1196	674	7.92	580	2.52
7 00	.500	110	359	235	3.26	1.65	.264	69	538	304	7.80	580	1.53
8 00	.542	87	419	253	4.81	1.84	.434	69	419	244	6.07	500	2.17
9 00	.661	87	449	268	5.15	1.78	1.434	274	628	451	2.29	180	2.58
10 00	.767	135	538	337	3.99	1.15	1.524	315	628	472	2.00	190	2.90
10 30	.784	160	458	309	2.86	1.25	...	...	...	...	....	...	....
11 00	.735	187	399	293	2.13	1.03	.771	178	478	328	2.68	190	1.46
11 30	.750	196	319	258	1.63	0.98	...	...	...	...	....	...	....
12 00	.752	206	329	268	1.60	0.83	.851	178	419	299	2.35	160	1.36
12 30	.828	224	349	287	1.56	0.91	...	...	...	...	....	...	....
13 00	.838	229	339	284	1.48	1.09	1.222	384	478	431	1.24	180	2.20
13 30	.775	242	439	340	1.81	1.24	...	...	...	...	....	...	....
14 00	.931	270	478	374	1.77	1.21	1.256	589	688	639	1.17	160	2.01
14 30	1.051	274	528	401	1.93	1.26	...	...	...	...	....	...	....
15 00	1.237	274	568	421	2.07	1.61	1.196	548	628	588	1.14	180	2.15
15 30	1.040	293	668	481	2.28	1.35	...	...	...	...	....	...	....
16 00	.937	379	907	643	2.40	1.22	.563	96	239	168	2.49	160	0.90
16 30	1.179	480	1106	793	2.30	1.77	...	...	...	...	....	...	....
17 00	1.515	516	1246	881	2.42	2.58	1.104	781	508	645	.65	150	1.66
17 30	1.840	507	1206	857	2.39	2.39	...	...	...	...	....	...	....
18 00	1.819	416	1206	811	2.90	3.09	1.300	370	538	454	1.46	110	1.43
18 30	1.738	311	1156	734	3.71	3.13	...	...	...	...	....	...	....
19 00	1.607	205	1076	641	5.24	4.02	1.372	425	448	437	1.06	90	1.23
19 30	1.475	141	967	554	6.85	5.16	...	...	...	...	....	...	....
20 00	1.366	82	897	490	10.94	6.01	[1.400]	[380]	[420]	[400]	1.10	20	0.28

[a] Bracketed figures refer to interpolated or extrapolated results.

[b] The various values below are the means of 3 consecutive observations centering at the hour and the half-hour; the values of i are derived with the aid of the P. G. quantities in Table 1-D.

No. 2.—Observations at the Stonyhurst Observatory, England.

The magnetograms for declination (*D*) and horizontal intensity (*H*) on August 21, 1914, were supplied by Director Walter Sidgreaves, S. J. Owing to a mishap the vertical intensity variometer was not in operation at the time in question. The results of our D-scalings are shown in Fig. 4, p. 83.

Table 2-A.—*Results of temperature measurements at the Stonyhurst Observatory on August 21, 1914.*

G.M.T.	Temp. (Fahr)	G.M.T.	Temp. (Fahr)	G.M.T.	Temp. (Fahr)	G.M.T.	Temp. (Fahr)	G.M.T.	Temp. (Fahr)
h m	°	h m	°	h m	°	h m	°	h m	°
10 00	64.0	11 00	64.4	12 00	63.7	13 00	63.9	14 00	62.0
05	64.5	05	64.4	05	63.6	05	64.0	05	61.9
10	64.7	10	64.3	10	63.5	10	64.0	10	61.8
15	64.9	15	64.5	15	63.5	15	64.6	15	61.9
20	64.5	20	64.6	20	63.4	20	64.6	20	62.0
25	64.6	25	65.0	25	63.2	25	64.5	25	62.0
30	64.6	30	65.1	30	63.4	30	64.4	30	61.8
35	64.5	35	65.2	35	63.3	35	64.2	35	61.8
40	64.6	40	64.7	40	63.1	40	64.0	40	62.0
45	64.5	45	64.3	45	63.1	45	63.7	45	62.1
50	64.4	50	63.9	50	63.0	50	63.4	50	62.0
55	64.4	55	63.8	55	63.2	55	63.2	55	62.0
								15 00	62.0

No. 3.—Observations at the Kew Observatory, England.

Dr. Chree's report has already appeared (*Terr. Mag.*, vol. 20, pp. 71-74). The declination curve given in Fig. 4 has been obtained from our scalings of the copy of the magnetogram supplied by Dr. Chree, supplemented by the values in Tables 1 and 2 of Chree's article.

No. 4.—Observations at the Rude Skov Observatory, Denmark.

Table 4-A gives the results of the *D*, *H*, and *Z* measurements supplied by Director C. H. Ryder for every minute from 10 A. M. to 3 P. M. Greenwich civil mean time. The table has been condensed from the original tables supplied, only the five-minute means being here given.

No. 5.—Observations at the Ksara Observatory, Syria.

The issue of *Comptes Rendus* (Paris) of October 27, 1914, contains, on pp. 614-615, an account by B. Berloty of some magnetic observations made at the Ksara Observatory on August 21, 1914,

TABLE 4-A—*Values of the magnetic elements at Rude Skov Observatory on August 21, 1914.*

G.M.T.	Decl'n (West)	Intensity Hor'l	Intensity Vert'l	G.M.T.	Decl'n (West)	Intensity Hor'l	Intensity Vert'l	G.M.T.	Decl'n (West)	Intensity Hor'l	Intensity Vert'l
h m	° '	γ	γ	h m	° '	γ	γ	h m	° '	γ	γ
10 01	8 54.1 a	17264 a	44587 a	11 45	8 56.7	17289	44594	13 25	8 57.0	17283	44602
05	53.8	60	587	50	56.5	89	594	30	56.7	81	603
10	53.9	61	587	55	56.3	88	594	35	56.4	84	604
15	54.4	63	588	12 00	55.9	88	594	40	56.0	82	604
20	54.9	65	589	05	55.4	86	594	45	55.8	85	605
25	55.0	65	589	10	55.2	85	594	50	55.8	86	606
30	54.6	64	590	15	55.0	88	595	55	55.7	86	606
35	54.5	65	590	20	55.3	88	596	14 00	55.8	87	607
40	54.5	66	590	25	55.7	88	597	05	55.6	85	607
45	54.5	68	591	30	56.3	88	597	10	55.2	85	607
50	54.7	71	591	35	56.8	88	598	15	55.2	89	608
55	55.3	76	592	40	57.0	89	598	20	55.1	90	608
11 00	55.5	79	593	45	57.2	86	598	25	54.7	90	608
05	55.7	80	593	50	57.1	85	598	30	54.5	90	608
10	56.0	81	593	55	57.2	85	599	35	54.3	91	608
15	56.3	83	593	13 00	57.5	85	599	40	53.9	91	609
20	56.4	85	593	05	57.6	84	599	45	53.5	92	609
25	56.7	85	593	10	57.4	84	600	50	53.4	93	609
30	56.9	85	593	15	57.4	85	601	55	53.2	94	609
35	56.9	87	593	20	57.2	83	602	59	b 52.9	b 94	b 610
40	56.7	88	594								

a Mean of the 3 values at $10^h\ 00^m$, $10^h\ 01^m$, and $10^h\ 02^m$.
b Mean of the 3 values at $14^h\ 58^m$, $14^h\ 59^m$, and $15^h\ 00^m$.

at the time of the solar eclipse. The position of this observatory is given as 33° 49.′4 N. and $2^h\ 14^m\ 12^s$ east of Paris, or $2^h\ 23^m\ 33^s$ (35° 53.′2) east of Greenwich. The eclipse was partial; the phase of maximum obscuration (about 0.87) occurred approximately at $13^h\ 21.^m5$ Greenwich civil mean time, or $15^h\ 45^m$ ($3^h\ 45^m$ P. M.) Ksara local mean time, August 21.

Unfortunately, the magnetograph was not in operation at the time. However, during the eclipse a member of the Observatory staff, Jacques Tonello, it is stated, made careful observations of the changes in the magnetic declination and the inclination. A Kew-pattern magnetometer and a Dover dip circle were used. As it is somewhat precarious to observe variations in the inclination by means of a dip circle, these observations are omitted here. Accordingly, only the declination results are found in Table 5-A. The author's differential values have been referred approximately to absolute values by assuming a base line of 0° 13′ W. as derived from the observed value of the declination on August 20, 1914, at

5 h 01 m P. M., Ksara m. t., 0° 16′ W. and the differential readings at the same time on August 21.

Berloty states that, according to some magnetograms of previous years, the phase of maximum west declination in August should occur normally between 1 and 2 P. M. (Ksara m. t.); thereafter west declination should decrease until reaching a minimum between 5 and 6 P. M. Instead, on the day of the eclipse the turning point, after which the decrease should set in, was retarded, and did not occur until 3 h 57 m P. M. (about 12 m after the phase of maximum obscuration), or two hours and more after the usual time. (See Table 5-A.)

Attention is also directed by Berloty to the large spot on Sun on this day, and the question is raised whether it will be possible to disentangle an eclipse magnetic effect from a disturbance connected with the sunspot.

TABLE 5-A.—*Magnetic declination observations at the Ksara Observatory on August 21, 1914.*

K.M.T.	G.M.T.	Decl'n (West)	K.M.T.	G.M.T.	Decl'n (West)	K.M.T.	G.M.T.	Decl'n (West)
h m	h m	° ′	h m	h m	° ′	h m	h m	° ′
13 32	11 08	0 13.0	15 12	12 48	0 15.8	16 12	13 48	0 17.1
47	23	13.0	17	53	15.1	17	53	17.1
14 02	38	13.2	22	58	16.3	22	58	16.7
17	53	13.6	27	13 03	16.3	27	14 03	16.7
32	12 08	14.1	32	08	16.5	32	08	16.7
37	13	14.5	37	13	16.5	37	13	16.7
42	18	14.7	42	18	16.9	42	18	16.5
47	23	14.7	47	23	17.1	47	23	16.5
52	28	14.9	52	28	17.1	17 02	38	16.3
57	33	14.9	57	33	17.4	17	53	16.3
15 02	38	15.0	16 02	38	17.3	32	14 08	16.3
07	43	15.4	07	43	17.3			

No. 6.—OBSERVATIONS AT THE EKATERINBURG OBSERVATORY, RUSSIA.

(*Communicated by H. Abels and P. Mueller.*)

The following magnetic and meteorological observations were made in accordance with the program given in the circular letter received from Dr. Bauer. The eye readings of the variometers were taken every minute on August 21, 1914, from 10 to 15 o'clock (3 P. M.) Greenwich mean civil time. The observers were Messrs. Korovin (10 to 11 A. M.), Putnin (11 to Noon), and Metnikov (Noon to 3 P. M.).

Various observers took part successively in the meteorological

observations; while some were taking the readings indoors of the barometer and of the anemometer, others were making simultaneously the outdoor observations. The geographic position of the Observatory is: 56° 49.′6 N.; 60° 38.′3 E. of Gr.

[Table 5-A has been condensed from the authors' original table. Instead of giving the original values for each minute, described above, five-minute means are given. For example, the values for 10ʰ 05ᵐ are the means of the readings from 10ʰ 03ᵐ to 10ʰ 07ᵐ. The values for 10ʰ 01ᵐ are the means of the three readings at 10ʰ 00ᵐ, 10ʰ 01ᵐ, and 10ʰ 02ᵐ. Similarly, the values for 14ʰ 59ᵐ are the means of the three readings at 14ʰ 58ᵐ, 14ʰ 59ᵐ, and 15ʰ 00ᵐ. The authors also sent with their report copies of the magnetograms for August 21, 1914.—*B.*]

TABLE 6-A.—*Results of magnetic observations at the Ekaterinburg Observatory on August 21, 1914.*

G.M.T.	Decl'n (East)	Intensity Hor'l	Intensity Vert'l	G.M.T.	Decl'n (East)	Intensity Hor'l	Intensity Vert'l	G.M.T.	Decl'n (East)	Intensity Hor'l	Intensity Vert'l
h m	° ′	γ	γ	h m	° ′	γ	γ	h m	° ′	γ	γ
7 00	10 57.6	17257	50863	11 30	10 56.8	17290	50865	14 00	11 03.2	17275	50868
15	57.4	56	63	35	56.8	91	66	05	02.9	74	68
30	57.0	61	62	40	56.7	92	67	10	02.7	73	67
45	56.3	62	60	45	56.8	93	67	15	02.4	76	67
8 00	55.9	66	58	50	56.9	93	67	20	01.9	76	67
15	55.6	68	60	55	57.1	91	67	25	01.8	76	67
30	55.5	67	55	12 00	57.4	90	67	30	01.7	77	66
45	56.0	64	54	05	57.9	89	67	35	01.5	78	66
9 00	55.4	72	54	10	58.3	89	66	40	01.2	78	65
15	55.0	77	56	15	58.2	91	67	45	01.0	77	64
30	55.0	76	58	20	58.4	89	66	50	00.8	78	64
45	55.1	77	61	25	58.7	87	66	55	00.8	78	64
10 01	55.8	76	62	30	58.9	85	67	59	01.0	79	64
05	56.4	72	62	35	59.2	84	67	15 15	00.7	78	64
10	56.6	71	62	40	59.8	83	68	30	00.5	79	63
15	56.6	72	62	45	11 00.7	81	68	45	00.4	80	63
20	56.8	74	62	50	01.3	79	68	16 00	00.2	84	62
25	57.1	76	62	55	01.7	78	69	15	00.5	84	61
30	57.3	78	62	13 00	01.9	77	70	30	00.1	85	61
35	57.4	80	62	05	02.2	76	70	45	00.9	84	60
40	57.5	80	62	10	02.5	77	71	17 00	01.1	83	60
45	57.6	82	62	15	02.6	78	71	15	01.1	88	60
50	57.4	84	62	20	02.9	77	71	30	00.5	88	59
55	57.3	87	63	25	02.8	78	71	45	00.6	86	59
11 00	57.0	90	63	30	03.1	74	70	18 00	00.2	85	58
05	57.0	90	64	35	03.0	76	70	15	11 00.2	85	59
10	57.1	90	64	40	03.2	75	69	30	10 59.9	84	58
15	56.9	91	64	45	03.3	75	68	45	11 00.2	83	58
20	56.7	91	65	50	03.2	75	68	19 00	00.0	82	58
25	56.7	91	65	55	03.3	75	68				

TABLE 6-B.—*Results of meteorological observations at the Ekaterinburg Observatory on August 21, 1914.*

G.M.T.	Pressure	Temp. of Air	Vapor Tension	Rel. Hum.	Wind Dir.	Wind Vel.	Cloudiness
h m	mm	°	mm	%		m	
10 00	733.1	27.0	9.5	35	S	8	⊙ 5 Ci, Ci-Cu, Cu
15	32.9	27.8	9.4	35	SSW	9	⊙ 4 Ci, Ci-S, Cu
30	32.8	27.6	9.5	35	S	10	⊙ 4 Ci, Ci-S, Cu
45	32.9	27.2	9.2	35	S	10	⊙ 4 Ci, Ci-S, Cu
11 00	32.9	26.8	9.1	35	S	7	⊙ 3 Ci, Cu
05	32.9	27.2	9.5	35	S	8	⊙ 4 Ci, Cu
10	32.9	27.4	9.3	35	S	10	⊙ 3 Ci, Ci-S, Cu
15	32.9	26.8	9.1	35	SSE	10	⊙ 3 Ci, Ci-S
20	32.9	26.8	9.1	35	SE	9	⊙ 3 Ci, Ci-S, Cu
25	32.8	26.8	9.1	35	S	9	⊙ 3 Ci, Ci-S, Cu
30	32.8	26.6	8.9	35	S	12	⊙ 2 Ci, Ci-S, Cu
35	32.8	26.8	9.1	35	SSE	9	⊙ 2 Ci, Ci-S, Ci-Cu, Cu
40	32.8	26.6	8.9	35	S	10	⊙ 2 Ci, Ci-S, Ci-Cu, Cu
45	32.8	26.7	8.8	35	SSE	9	⊙ 2 Ci, Ci-S, Ci-Cu, Cu
50	32.8	27.0	8.8	34	SSE	9	⊙ 2 Ci, Ci-S, Ci-Cu, Cu
55	32.8	26.6	8.3	33	S	9	⊙ 2 Ci, Ci-S, Ci-Cu
12 00	32.8	26.6	8.9	35	S	10	⊙ 3 Ci, Ci-S, Ci-Cu, Cu
05	32.8	26.7	9.0	35	S	9	⊙ 3 Ci, Ci-S, Ci-Cu, Cu
10	32.8	26.5	8.8	35	S	9	⊙ 3 Ci, Ci-S, Ci-Cu, Cu
15	32.8	26.4	8.9	35	S	8	⊙ 3 Ci, Ci-S, Ci-Cu, Cu
20	32.8	26.4	8.9	35	S	6	⊙ 3 Ci, Ci-S, Ci-Cu, Cu
25	32.8	26.2	8.9	35	S	8	⊙ 3 Ci, Ci-S, Ci-Cu, Cu
30	32.7	26.0	8.9	36	S	7	⊙ 3 Ci, Ci-S, Ci-Cu, Cu
35	32.7	25.8	8.8	36	S	8	⊙ 3 Ci, Ci-S, Ci-Cu, Cu
40	32.7	25.6	9.0	37	S	7	⊙ 3 Ci, Ci-S, Ci-Cu
45	32.7	25.6	9.0	37	S	7	⊙ 2 Ci, Ci-S, Ci-Cu
50	32.7	25.4	8.9	37	S	6	⊙ 3 Ci, Ci-S, Ci-Cu
55	32.7	25.4	8.9	37	S	6	⊙ 3 Ci, Ci-S, Ci-Cu
13 00	32.7	25.3	9.0	37	S	6	⊙ 2 Ci, Ci-Cu
05	32.7	25.2	9.1	38	SSE	5	⊙ 1 Ci, Ci-Cu
10	32.7	25.2	9.1	38	S	6	⊙ 1 Ci, Ci-Cu
15	32.7	25.2	9.1	38	SSE	5	⊙ 1 Ci, Ci-Cu
20	32.7	25.2	9.4	39	SSE	6	⊙ 1 Ci, Ci-Cu
25	32.7	25.2	9.5	39	S	5	⊙ 1 Ci, Ci-Cu
30	32.6	25.2	9.2	38	S	6	⊙ 1 Ci, Ci-Cu
35	32.6	25.2	9.1	38	SSE	6	⊙ 1 Ci, Ci-Cu
40	32.6	25.4	9.4	39	SSE	7	⊙ 0
45	32.6	25.3	9.1	38	S	6	⊙ 0
50	32.7	25.2	9.1	38	S	6	⊙ 0
55	32.7	25.2	8.9	37	S	6	⊙ 0
14 00	32.7	25.0	9.0	38	S	7	⊙ 1 Ci, Ci-Cu
05	32.7	25.0	8.9	37	S	6	⊙ 1 Ci, Ci-Cu
10	32.7	24.8	9.0	38	S	7	⊙ 1 Ci, Ci-Cu
15	32.7	24.8	8.9	38	S	7	⊙ 1 Ci, Ci-Cu
20	32.7	24.7	8.9	38	S	7	⊙ 1 Ci, Ci-Cu
25	32.7	24.6	9.0	39	S	7	⊙ 1 Ci, Ci-Cu
30	32.7	24.4	9.0	39	S	7	⊙ 1 Ci, Ci-Cu
35	32.8	24.2	9.1	40	S	6	⊙ 1 Ci, Ci-Cu
40	32.8	24.1	9.0	40	S	5	⊙ 0
45	32.8	23.8	9.2	41	S	5	⊙ 0
50	32.8	23.5	9.2	42	SE	5	⊙ 1 Ci, Ci-Cu
55	32.8	23.3	9.2	43	SE	5	⊙ 2 Ci, Ci-Cu
15 00	32.8	23.1	9.2	43	SE	5	⊙ 2 Ci, Ci-Cu

No. 7. Observations at Mauritius Observatory, Aug. 21, 1914.

(Communicated by A. Walter, Director.)

G. M. T.	MAGNETIC*a*			METEOROLOGICAL*a*							
	Absolute Values			Barometer	Temperature		Wind		Cloud (0-10)		
	W. Decl.	Hor. Int.	Ver. Int.	Pressure	Air	Evap.	Direction*b*	Velocity*c*	Upper	Lower	Remarks
h m	° ′	γ	γ	in.	°	°	pts.	miles			
9 55	9 35.1	23242	31012								Weather
10 00	34.9	41	12	29.938	75.1	65.9	10		1	1	fine
05	34.9	39	12					3			through-
10	34.7	38	11	932	75.2	65.3					out
15	34.7	39	12				10		1	1	period
20	34.5	39	12	930	75.0	65.7		2			
25	34.5	40	12								
30	34.3	41	12	929	74.9	66.0	10		0	1	
35	34.3	41	12								
40	34.3	42	13	928	74.7	65.8		2			
45	34.1	43	13				10		0	2	
50	33.9	43	13	929	74.7	65.9					
55	33.9	44	13					7			
11 00	33.9	45	12	930	74.6	65.7	11		0	2	
05	33.7	45	12								
10	33.7	45	12	931	74.5	65.6		7			
15	33.7	45	12				10		0	1	
20	33.7	44	12	934	74.5	65.7					
25	33.7	44	12					7			
30	33.9	43	12	939	74.1	65.7	10		0	2	
35	33.9	42	11								
40	33.9	41	12	938	73.7	65.7		4			
45	33.7	40	12				10		0	1	
50	33.7	39	13	939	73.6	65.6					
55	33.9	38	13					3			
12 00	33.9	37	14	938	73.5	65.9	10		0	1	
05	33.9	37	14								
10	34.1	36	15	942	72.9	65.7		4			
15	34.1	36	15				10		0	1	
20	34.1	35	16	945	72.1	75.5					
25	34.1	34	16					5			
30	34.3	33	16	949	71.9	65.0	10		0	2	
35	34.5	32	16								
40	34.9	31	17	951	71.6	64.9		5			
45	34.9	30	18				10		0	2	
50	34.7	29	18	950	71.7	64.7					
55	34.7	28	19					5			
13 00	34.7	27	20	952	71.3	64.6	10		0	3	
05	34.9	26	20								
10	34.9	26	21	955	70.8	64.5		3			
15	35.1	25	22				9		0	3	
20	35.1	25	22	957	70.6	64.3					
25	35.1	25	23					8			
30	35.3	25	24	959	70.5	64.2	10		1	3	
35	35.3	25	24								
40	35.3	25	24	960	70.3	64.1		5			
45	35.5	25	24				10		1	2	
50	35.5	25	24	963	69.9	64.1					
55	35.5	25	24					3			
14 00	35.5	25	24	966	69.8	64.0	9		1	4	
05	35.5	25	24					3			
10	35.7	25	24	969	69.7	64.1					
15	35.7	25	24				10		1	3	
20	35.7	26	24	971	69.6	64.0		4			
25	35.9	26	24								
30	35.9	27	24	972	69.5	63.9	10		1	3	
35	35.9	27	24								
40	35.9	28	24	975	69.3	63.8		3			
45	36.1	28	24				9		2	2	
50	36.1	28	24	977	69.2	63.7					
55	36.1	28	24					3			
15 00	35.9	28	24	979	68.8	63.7	10		2	3	

a Change of temperature during observations in basement nil.
b N = 0; E = 8; S = 16; W = 24 points. *c* Miles per 15 minutes.

No. 8. Data for Bombay and Alibag Observatories, Aug. 21, 1914. (*Communicated by N. A. F. Moos, Director.*)

G. M. T.	Absolute values of magnetic elements at Alibag: Decl'n (East)	Intensity: Hor'l	Intensity: Vert'l	Values of meteorological elements at Bombay (Colaba): Temp. of air (Fahr.)	Wet Bulb Temp. (Fahr.)	Bar. Press corr'd for mean s. l. and gr. v	Wind: Velocity miles per hour	Wind: Dir.
h m	° ′	γ	γ	°	°	in.		
10 00	0 43.3	36884	16609	84.0	78.5	29.651	12	W
05	43.5	81	610	83.9	78.8	649	11	W
10	43.7	79	611	84.1	79.2	647	10	W
15	43.8	79	611	84.2	78.8	647	11	W
20	44.0	79	612	84.2	78.8	647	12	W
25	44.0	78	611	84.2	78.8	647	12	W
30	44.2	79	612	84.2	78.6	645	12	W
35	44.3	79	612	84.1	77.8	645	12	W
40	44.4	78	612	84.1	78.0	644	14	W
45	44.5	78	612	84.1	78.1	643	13	W
50	44.6	79	612	84.2	78.4	643	14	W
55	44.6	79	611	84.1	77.9	643	14	W
11 00	44.6	80	610	83.9	77.7	642	14	W
05	44.7	80	610	83.9	77.5	641	14	W
10	44.7	79	610	83.9	77.4	643	14	W
15	44.8	78	610	83.9	77.7	644	13	W
20	44.8	78	610	83.9	77.8	643	13	W
25	44.8	77	609	83.9	77.7	641	14	W
30	44.8	76	608	83.9	77.6	637	13	W
35	44.9	75	607	83.9	77.5	637	13	W
40	44.9	75	607	83.7	77.9	639	12	W
45	45.0	74	606	83.7	77.6	639	12	W
50	44.9	73	604	83.7	77.6	639	12	W
55	44.9	72	603	83.7	77.7	640	11	W
12 00	45.0	71	602	83.6	77.6	641	10	W
05	45.0	71	602	83.4	77.7	641	10	W
10	45.0	70	601	83.3	77.6	641	12	W
15	45.0	70	599	83.4	77.8	641	12	W
20	45.0	70	598	83.3	77.2	641	12	W
25	44.9	68	598	83.0	77.3	642	14	W
30	44.9	67	597	82.8	77.0	643	14	W
35	44.9	66	595	82.7	76.9	643	14	W
40	44.9	66	595	82.6	76.7	643	13	W
45	44.9	65	594	82.6	77.0	642	12	W
50	44.8	64	593	82.6	77.2	642	12	W
55	44.8	63	593	82.5	76.9	644	11	W
13 00	44.8	62	592	82.3	76.7	644	11	W
05	44.7	62	591	82.3	76.9	646	11	W
10	44.6	62	589	82.3	76.4	648	12	W
15	44.4	62	590	82.2	76.3	649	11	W
20	44.4	61	589	82.2	76.5	651	11	W
25	44.2	61	589	82.1	76.5	653	11	W
30	44.2	61	589	82.1	76.5	655	12	W
35	44.1	60	588	81.7	76.4	656	12	W
40	44.0	60	589	81.7	76.3	657	12	W
45	44.0	60	589	81.7	76.5	659	12	W
50	44.0	60	590	82.3	76.4	658	12	W
55	44.1	59	589	81.6	76.5	659	12	W
14 00	44.0	58	590	81.5	76.6	661	12	W
05	44.0	58	589	81.5	76.3	663	12	W
10	43.9	58	590	81.4	76.2	664	12	W
15	43.9	59	590	81.4	76.0	666	12	W
20	43.8	60	589	81.2	76.4	667	12	W
25	43.8	60	590	81.2	76.2	671	12	W
30	43.8	61	589	81.2	76.2	675	11	W
35	43.7	62	589	81.2	76.2	674	11	W
40	43.6	63	589	81.2	76.5	675	10	W
45	43.6	63	590	81.2	76.7	677	9	W
50	43.6	64	590	81.2	76.7	679	11	W
55	43.6	64	590	80.1	75.7	680	8	W
15 00	43.6	64	591	80.1	75.8	683	8	W

Table 8-B.—Average hourly values derived from all days in the month of August, 1914.

G. M. T. Hour (*a*)	10	11	12	13	14	15
	° ′	° ′	° ′	° ′	° ′	° ′
Declination	0 42.8 E	0 43.8 E	0 44.4 E	0 44.3 E	0 43.7 E	0 43.6 E
	γ	γ	γ	γ	γ	γ
Horizontal Intensity	36885	36877	36870	36866	36866	36867
Vertical Intensity	16594	16597	16596	16590	16587	16589
	°	°	°	°	°	°
Temperature of air	82.9 F	82.4 F	81.6 F	81.0 F	80.6 F	80.4 F
Wet Bulb Temp.	78.6 F	78.2 F	77.7 F	77.4 F	77.1 F	77.1 F
	in.	in.	in.	in.	in.	in.
Barometric Pressure	29.666	29.659	29.662	29.673	29.689	29.705

(*a*) The hours as given denote exact full hours of G. M. T. for the magnetic elements; those for temperature, dry and wet, denote 11 minutes past the full hour; and those for barographs, 16 minutes past the full hour, as the measurements of the curves are made always at these exact instants of time.

NOS. 9 AND 10.—MAGNETIC OBSERVATIONS AT THE DEHRA DUN AND THE KODAIKANAL MAGNETIC OBSERVATORIES DURING THE SOLAR ECLIPSE OF AUGUST 21, 1914.

(*Communicated by Captain R. Thomas, R.E.*)

In response to Dr. Bauer's circular letter requesting cooperation in the special program of magnetic observations during the solar eclipse of August 21, 1914, the following observations were taken at the Dehra Dun and the Kodaikanal magnetic observatories.

Dehra Dun. Magnetometer *H*-observations: Full deflection observations were made at the commencement of every hour during the desired period, scale readings being taken every minute between the deflection observations. Corrections for change of declination and temperature were applied to the scale readings and the variations in *H* between two sets of deflection observations were then derived from the changes in the resulting deflection angles. Magnetometer *D*-observations: Two full sets of declination were made at the beginning and subsequently scale readings were taken every minute.

Kodaikanal. Magnetograph eye readings were made every

half minute; as only one observer was available, magnetometer observations could not be made.

Tables 9-A and 10-A are abstracts of the observations at both observatories; in order to reduce the observing error the means of five-minute observations have been taken out.

TABLE 9-A.—*Abstract of magnetic observations taken at Dehra Dun during the solar eclipse on August 21, 1914*

G. M. T.	Declination: From Magnetometer *E* 2° +	Declination: From Magnetograph *E* 2° +	Hor. Int.: From Magnetometer 33000γ +	Hor. Int.: From Magnetograph 33000γ +	V. Int.: From Magnetograph 32000γ +	G. M. T.	Declination: From Magnetometer *E* 2° +	Declination: From Magnetograph *E* 2° +	Hor. Int.: From Magnetometer 33000γ +	Hor. Int.: From Magnetograph 33000γ +	V. Int.: From Magnetograph 32000γ +
h m	′	′	γ	γ	γ	h m	′	′	γ	γ	γ
10 00	17.9	18.1	182	179	486	12 35	19.6	19.4	152	155	486
05	18.1	18.3	175	176	486	40	19.6	19.4	151	155	486
10	18.3	18.4	175	173	486	45	19.7	19.4	150	154	486
15	18.5	18.5	174	172	486	50	19.7	19.5	149	153	486
20	18.7	18.6	174	172	486	55	19.7	19.5	...	153	485
25	18.8	18.7	175	173	487	13 00	19.7	19.5	151*d*	151	485
30	18.8	18.9	172	173	488	05	19.8	19.5	...	150	485
35	18.9	19.0	174	173	489	10	19.6	19.4	145	152	485
40	19.2	19.1	175	172	490	15	19.4	19.4	145	152	485
45	19.4	19.2	176	172	490	20	19.5	19.3	150	150	485
50	19.4	19.3	176	173	490	25	19.7	19.3	155	151	486
55	19.4	19.3	179	173	490	30	19.7	19.3	156	150	486
11 00	19.3	19.3	176*a*	174	490	35	19.7	19.3	157	150	486
05	19.3	19.2	179*b*	174	490	40	19.6	19.2	159	150	486
10	19.4	19.4	.....	172	490	45	19.4	19.2	153	150	486
15	19.4	19.4	178	172	490	50	19.3	19.2	149	149	486
20	19.4	19.4	175	171	489	55	19.2	19.2	...	149	486
25	19.4	19.3	173	170	489	14 00	19.2	19.2	145*e*	148	487
30	19.5	19.4	169	167	488	05	19.2	19.1	...	148	486
35	19.6	19.4	169	167	487	10	19.3	19.2	147	149	487
40	19.6	19.4	167	166	487	15	19.3	19.2	151	149	488
45	19.6	19.5	165	164	487	20	19.2	19.0	152	150	488
50	19.7	19.5	166	163	487	25	19.0	18.9	150	151	490
55	19.7	19.5	.....	162	486	30	18.9	18.9	153	153	490
12 00	19.7	19.5	160*c*	161	486	35	18.8	18.8	155	154	490
05	19.7	19.5	.....	161	486	40	18.7	18.6	153	154	490
10	19.7	19.5	160	160	486	45	18.6	18.4	155	155	490
15	19.6	19.5	156	159	486	50	18.6	18.4	157	156	491
20	19.6	19.4	153	158	486	55	18.6	18.4	156	157	491
25	19.6	19.4	154	158	486	15 00	.....	18.5	...	156	491
30	19.6	19.4	150	156	486	06	18.7	18.5	156	158	491

a At 11^h 02^m. *b* At 11^h 08^m. *c* At 12^h 01^m. *d* At 13^h 03^m. *e* At 14^h 02^m.

TABLE 10-A.—*Abstract of magnetic observations taken at Kodaikanal during the solar eclipse on August 21, 1914.*

G. M. T.	Decl'n (West)	Intensity Hor'l	Intensity Vert'l	G. M. T.	Decl'n (West)	Intensity Hor'l	Intensity Vert'l
h m	° ′	γ	γ	h m	° ′	γ	γ
10 00	1 17.8	37540	2792	12 35	1 16.7	37556	2767
05	17.7	537	792	40	16.8	557	767
10	17.5	535	790	45	16.8	557	765
15	17.5	534	789	50	16.8	557	764
20	16.9	535	791	55	16.8	556	764
25	16.8	535	791	13 00	16.8	556	762
30	16.8	536	792	05	16.9	556	761
35	16.8	535	792	10	17.2	556	761
40	16.7	535	792	15	17.7	556	761
45	16.7	536	792	20	17.8	556	760
50	16.7	537	791	25	17.8	555	760
55	16.7	538	791	30	17.8	553	760
11 00	16.6	540	790	35	17.8	553	759
05	16.6	541	789	40	17.8	551	759
10	16.6	542	789	45	17.9	551	759
15	16.6	543	788	50	17.9	550	759
20	16.6	543	788	55	17.9	550	759
25	16.6	543	787	14 00	17.9	550	759
30	16.6	543	786	05	17.9	550	759
35	16.6	545	785	10	17.9	550	759
40	16.6	546	783	15	17.9	550	759
45	16.6	548	783	20	17.9	550	759
50	16.6	549	780	25	17.9	550	760
55	16.6	550	778	30	17.9	550	763
12 00	16.6	550	775	35	17.9	551	764
05	16.6	552	774	40	17.9	552	764
10	16.6	554	773	45	17.9	553	764
15	16.6	555	773	50	17.9	553	764
20	16.6	556	773	55	17.9	554	764
25	16.6	556	772	15 00	17.9	553	764
30	16.6	556	768				

No. 11.—MAGNETIC AND METEOROLOGICAL OBSERVATIONS MADE AT THE LUKIAPANG OBSERVATORY DURING THE TIME OF THE SOLAR ECLIPSE OF AUGUST 21, 1914.

(*Communicated by J. de Moidrey, S.J.*)

In spite of our distance from the provinces where the eclipse of August 21, 1914, was to be visible, I was getting ready to make certain observations when Dr. Bauer's circular of June 23, 1914, reached me. We have not followed it exactly, but the following shows what has been done. I note that the fine sun-spot which was crossing the disc, while it did not produce a great perturbation, produced waves at our station probably more noticeable than an effect of the eclipse.

Magnetographs. Calibrations were made on August 20 and 22. Although the sensitiveness of the balance was very insufficient, we preferred not to touch the instrument for fear of altering the base line.

Below is given the value of 1 mm. during the eclipse:

$$dD = 0'.48;\ dH = 2.3\gamma;\ dZ = 6.2\gamma.$$

The temperatures under the bell jars were:

Greenwich Mean Time	For H	For Z
h	°	°
7	31.20	31.15
12	31.20	31.15
25	31.02	31.00

The temperature coefficients are: $q_h = 38.1$ and $q_z = 28.1$.

Besides the automatic even-hour interruptions, a more exact mark was made at $9^h\ 51^m$ and at $15^h\ 03^m$, care having been taken to obtain the precise time by telephone from Zi-ka-wei. The precise point which corresponds to these hours is the mean of the interruption of the curves, either of the base line or of the other, the interruptions being indicated by the little arrow. (See Fig. 3.)

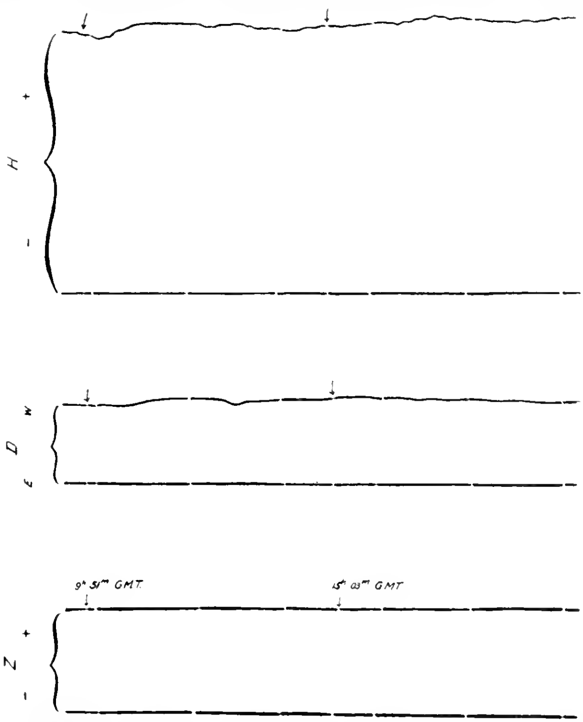


FIG. 3.—Magnetograms at Lukiapang Observatory, August 21, 1914; outside of Eclipse Limits. (Reduction, 2. 5.)

Meteorological Observations. The condition of the registering apparatus was verified, and Mr. Ignace Li read by Greenwich time the Fuess psychrometer and the Tonnelot barometer. The latter is here reduced to 0, at sea level and normal gravity.

G. M. T.	Dry Thermometer	Wet Thermometer	Barometric Pressure
h	°	°	mm
10	27.6	26.1	752.32
11	26.3	25.7	752.36
12	26.0	25 1	752.91
13	25.2	24.9	753.54
14	24.9	24.6	753.56
15	24.7	24.5	753.39
24	28.0	26 0	752.84

No. 12.—Observations at the Antipolo Magnetic Observatory, Philippines.

(*Communicated by M. Saderra Maso, Assistant Director.*)

Table 12-A—*Magnetic declination readings and meteorological observations at the Antipolo Magnetic Observatory on August 21, 1914.*

G. M. T.	Δ D [a]	Air Temp.	Wind Direc.	Wind Force	Weather	G. M. T.	Δ D [a]	Air Temp.	Wind Direc.	Wind Force	Weather
h m	′	°				h m	′	°			
10 00	0.00	23.8	SW	2	Rainy	12 30	−0.92	22.5	SW	5	Squally
05	0 00	23.8	"	"	"	35	−0.95	22.3	"	5-3	"
10	0.00	23.8	"	"	"	40	−1 08	22.1	"	3-4	"
15	−0.40	23.8	"	"	Overcast	45	−1.18	22.1	NW	5-4	"
20	−0.67	23.8	"	"	"	50	−1 25	22.0	SW	4-6	"
25	−0.67	23 8	"	"	"	55	−1.40	22.0	"	6	"
30	−0.67	23 8	"	"	Fog	13 00	−1.50	22.0	NW	5	"
35	−0.75	23.8	W	1	"	05	−1.58	22.0	"	"	"
40	−0.75	23.8	"	"	"	10	−1.58	22.1	"	"	"
45	−0.80	23.8	SW	2	Drizzle	15	−1.63	22.2	"	"	"
50	−0 80	23.9	"	"	Overcast	20	−1.83	22.2	"	"	"
55	−0.80	23.9	"	"	"	25	−1.79	22.1	"	"	"
11 00	−0.80	23.9	"	1	"	30	−1.63	22.0	SW	5-4	"
05	−0.80	23.9	W	"	"	35	−1.63	22.0	"	4	"
10	−0.80	24.0	"	"	"	40	−1.63	22.0	"	"	"
15	−0.80	24.0	"	"	"	45	−1.63	22.0	"	"	"
20	−0.80	24.0	"	"	"	50	−1.63	22 0	"	"	"
25	−1.00	24.1	SW	3	Squally	55	−1.63	22.0	"	"	"
30	−1.00	24 1	"	"	Thun., Rainy	14 00	−1.63	22.0	"	4-3	"
35	−1.00	24.0	"	"	Rainy	05	−1.60	22.0	"	3	"
40	−1.00	23.9	"	"	Heavy Rain	10	−1.58	22.0	"	"	"
45	−1.00	23.8	"	4	Squally	15	−1.56	22.0	"	"	"
50	−1 00	23.6	"	"	"	20	−1.55	22.0	"	"	"
55	−1.00	23.5	N	3-4	Thun. Show.	25	−1.55	22 0	"	"	"
12 00	−0.94	23.4	N	3-4	Heavy rain	30	−1.52	22.0	"	3-2	"
05	−0.92	23.2	N	4	"	35	−1.50	22.0	"	2	"
10	−0.92	23.1	SW	3	Overcast	40	−1.50	22 0	"	"	"
15	−0.92	23.0	"	"	Ov't, Light'g	45	−1.46	22.0	"	"	"
20	−0.92	22.8	"	4-3	Overcast	50	−1.42	22.0	"	"	"
25	−0.92	22.6	"	3-5	Ov't, Squally	55	−1.42	22.0	"	"	"

a The author does not explain the meaning of the sign −; it is assumed that increasing negative quantities indicate westward motion of north end of needle.—*B.*

No. 13.—Observations at the Agincourt Observatory, Canada.

(*Communicated by R. F. Stupart, Director.*)

Table 13-A.—*Values of the magnetic elements at Agincourt Observatory on August 21, 1914.a*

G.M.T.	Decl'n (West)	Hor'l Int.	G.M.T.	Decl'n (West)	Hor'l Int.	G.M.T.	Decl'n (West)	Hor'l Int.
h m	° '	γ	h m	° '	γ	h m	° '	γ
10 01	6 25.8	16072	11 45	6 21.1	16081	13 25	6 21.9	16061
05	26.9	70	50	20.8	82	30	22.3	60
10	27.3	69	55	20.6	83	35	22.4	59
15	27.2	70	12 00	20.6	82	40	22.8	56
20	27.5	70	05	20.5	82	45	22.6	53
25	27.0	73	10	20.6	82	50	22.6	53
30	26.4	74	15	20.0	81	55	23.1	50
35	26.1	74	20	19.5	81	14 00	23.3	48
40	25.8	74	25	19.4	80	05	24.1	48
45	25.7	75	30	19.6	79	10	24.6	47
50	25.4	77	35	20.1	77	15	24.6	46
55	24.5	79	40	20.0	74	20	25.0	46
11 00	23.8	80	45	20.8	71	25	25.1	45
05	23.5	80	50	21.2	70	30	25.3	44
10	23.1	81	55	21.4	69	35	25.6	43
15	22.6	82	13 00	21.0	68	40	25.7	42
20	22.5	83	05	21.0	67	45	25.8	40
25	22.4	82	10	21.2	66	50	26.0	39
30	22.1	82	15	21.4	63	55	26.5	39
35	22.0	81	20	21.9	61	59	26.8	39
40	21.6	81						

a The original table gave the values for every minute. Only the five-minute means are published here. The values at $10^h\ 01^m$ and $14^h\ 59^m$ are each the mean of three readings.—*B.*

Nos. 14, 15, 16, 17, 18.—Observations at the United States Magnetic Observatories (Porto Rico, Cheltenham, Tucson, Sitka, and Honolulu).

The results of the magnetic observations at these Observatories will be found in this journal, vol. 21, pp. 9-14.

Nos. 19, 20, 21, 22, 23.—Magnetic Observations by the Department of Terrestrial Magnetism.

The following observations were made in accordance with special instructions sent to the observers of the Department of Terrestrial Magnetism. Declination readings were made, as nearly as possible, on the full minute G. M. T. for every minute during the prescribed interval on August 21, 1914. Unfavorable weather

Tables Nos. 19, 20, 21, 22, 23.—*Magnetic declinations on August 21, 1914.*

G. M. T.	No. 19 Washington, D. C.	No. 20 Burwell, Labrador	No. 21 Ruwe, Belgian Congo	No. 22 Dessié, Abyssinia	No. 23 Canton, China
h m	′	° ′	° ′	° ′	° ′
10 01	4 31.5W	41 21.5W	12 21.5W	1 42.2W	0 20.1W
05	32.0	19.3	21.3	42.1	20.2
10	32.4	17.8	21.2	42.1	20.3
15	32.7	21.8	21.2	41.9	20.3
20	32.8	26.3	20.9	41.7	20.3
25	32.6	27.1	20.9	41.7	20.3
30	32.1	27.5	20.7	41.8	20.3
35	31.7	23.2	20.5	42.0	20.3
40	31.4	20.7	20.4	42.1	20.4
45	31.2	21.2	20.3	42.0	20.4
50	31.0	24.5	20.2	41.9	20.5
55	30.5	25.7	20.1	41.9	20.6
11 00	30.0	26.6	19.9	41.9	20.9
05	29.7	30.0	19.7	42.1	21.1
10	29.5	32.0	19.6	42.1	21.2
15	29.0	32.5	19.6	42.3	21.3
20	28.9	32.1	19.5	42.3	21.4
25	28.9	34.4	19.4	42.3	21.6
30	28.6	33.5	19.1	42.2	21.7
35	28.5	35.6	19.0	42.1	21.7
40	28.1	36.7	18.9	42.1	21.7
45	27.7	39.7	18.8	41.9	22.0
50	27.4	41.1	18.7	41.7	21.9
55	27.4	41.3	18.6	41.5	22.0
12 00	27.4	39.9	18.5	41.5	21.9
05	27.2	36.0	18.3	41.3	22.0
10	27.3	37.3	18.3	41.2	22.1
15	26.9	36.6	18.3	41.1	21.8
20	26.5	35.9	18.3	41.1	21.6
25	26.4	37.7	18.4	41.1	21.5
30	26.5	36.5	18.4	41.3	21.4
35	26.5	36.7	18.5	41.2	21.3
40	26.4	38.7	18.4	41.2	21.1
45	26.8	41.3	18.5	41.1	20.8
50	27.2	41.3	18.4	41.0	20.6
55	27.4	42.9	18.4	40.9	20.3
13 00	27.3	43.2	18.4	40.9	20.3
05	27.2	38.9	18.4	40.8	20.3
10	27.3	40.5	18.5	40.8	20.3
15	27.3	40.5	18.6	40.9	20.3
20	27.8	40.9	18.6	40.8	20.3
25	28.1	43.4	18.5	40.8	20.3
30	28.6	....	18.5	40.6	20.3
35	28.6	....	18.5	40.6	20.3
40	29.0	....	18.4	40.4	20.3
45	28.9	....	18.4	40.2	20.3
50	29.0	....	18.4	40.1	20.3
55	29.2	....	18.4	40.0	20.4
14 00	29.7	....	18.5	39.9	20.3
05	30.1	....	18.5	39.7	20.4
10	30.7	....	18.6	39.8	20.3
15	30.9	....	18.6	40.0	20.3
20	31.2	....	18.7	40.1	20.3
25	31.4	....	18.8	40.3	20.3
30	31.7	....	18.9	40.4	20.3
35	31.7	....	18.9	40.5	20.3
40	31.9	....	19.1	40.7	20.3
45	32.0	....	19.2	40.8	20.2
50	31.9	....	19.4	40.9	20.1
55	32.1	....	19.5	40.9	20.1
59	32.3	....	19.6	40.9	20.2

interfered somewhat with the observational program at Burwell, Labrador. There are some slight uncertainties in the times of the readings at stations Nos. 20, 21, and 22, owing either to lack of precise knowledge of longitude of station, or because of failure to secure time observations on account of bad weather. In the table the five-minute mean results are given.

The stations, instruments, and observers are as follows:

No.	Station	Magnetometer	Observer
19	Washington, D.C.	C. I. W. No. 7	J. A. Fleming
20	Burwell, Labrador	C. I. W. No. 13	W. J. Peters and D. W. Berky
21	Ruwe, Belgian Congo	C. I. W. No. 16	D. M. Wise
22	Dessié, Abyssinia	C. I. W. No. 10	W. F. Wallis
23	Canton (Honglok), China	C. I. W. No. 12	C. K. Edmunds

On the Atmospheric-Electric Observations Made During the Solar Eclipse of August 21, 1914, at Kew and Eskdalemuir.

(*Abstract of Preliminary Report by Dr. W. F. G. Swann.*)

The records of the observations received from Kew and Eskdalemuir observatories have been examined, and plotted. The general irregularities of the curves make it very difficult to draw any conclusions as to the effect of the eclipse. Perhaps the nearest approach to a definite indication of a relation was found in the case of the *potential-gradient*. Here, both in the case of the observations at Eskdalemuir and at Kew, the element showed a depression with a minimum at the time of the maximum obscuration. This minimum was absent in the Eskdalemuir observations for August 20, and, while it was present on August 22, it was much less pronounced than on August 21.

The *conductivity curve* for Eskdalemuir shows a minimum during the first half of the period of the obscuration, but as this minimum also occurred on August 20 and 22, it cannot be definitely associated with the eclipse. Analogous remarks apply to the curves for the air-earth current and for the average charge density, $\frac{1}{2}(E_+ + E_-)$.

Since the variations which atmospheric-electric quantities are apt to show in a short period of time are so large (being of an order of magnitude equal to that of the whole of the quantity measured), it is felt that only after the accumulation of data from many sets of

eclipse observations will it be possible to speak with anything like certainty regarding the influence of the eclipse on such phenomena.

ATMOSPHERIC-ELECTRIC OBSERVATIONS MADE AT THE LABORATORY OF THE DEPARTMENT OF TERRESTRIAL MAGNETISM, WASHINGTON, D. C., DURING THE SOLAR ECLIPSE OF AUGUST 21, 1914.

(*Abstract of Report by Dr. W. F. G. Swann.*)

Although the city of Washington was far removed from the belt of totality, being in fact just within the eclipse limits, it was considered desirable to attempt observations. These observations comprised measurements of the potential-gradient and of the conductivities (λ_+ and λ_-) for positive and negative ions, but the measurements of the potential-gradient were only relative. The observations extended from a time just prior to commencement of the eclipse to about 1.5 hours after its completion.

The potential-gradient was on the average somewhat smaller during the period of the eclipse than it was immediately before and after, but the variation was not large enough, compared witn the natural irregularities, to warrant any certainty as to a connection between the phenomena. λ_+ showed a slight increase during the period of the eclipse, while λ_- showed a tendency in the reverse direction. Here again, however, the magnitudes of the changes were not so marked but that one might naturally attribute them to phenomena independent of the eclipse.

PRELIMINARY REVIEW OF MAGNETIC RESULTS.

We have plotted according to Greenwich mean time the curves showing the changes of the magnetic elements at the various stations for which the data are published in this report. It appears that August 21, 1914, was not wholly undisturbed, which fact was shown, however, to any marked extent, only at extreme northerly stations like Sitka, Alaska, and Burwell, Labrador. Various observers called attention to the good-sized Sun-spot seen on this day.[3]

[3] Regarding this spot, F. C. DENNETT reports in the October, 1914, issue of *Knowledge* (p. 379) as follows:

"No. 24.—A fine spot, first seen on August 13, 1914, within the northeastern limb, followed by a faculic area. From August 16-22 some small pores clustered round its eastern half; none, however, were very persistent. There were also some penumbral extensions, which, on August 21, reached a maximum diameter of 36,000 miles; but the usual diameter of the spot was 26,000 miles, and the length of the group, 45,000 miles. On August 18, the umbra was almost broken into three by very pale bridges. A bright tongue projected into it from the east, August 19-21. The northern part of the umbra was quite cut off on August 23-25. The spot was last seen on August 26. . . . During the eclipse on August 21, No. 24 was a beautiful object. Its dark umbra was, however, markedly less dark than the advancing rugged limb of the Moon, which presently covered it. It was of large size, but the spectroscope showed comparatively little disturbance."

In general, for the stations considered, the effect of any magnetic disturbance, which may have to be associated rather with the Sun-spot than with the solar eclipse, was of a moderate character; the mean "magnetic character" of August 21 was only 0.3.[4]

Table A gives the geographic positions of the various stations, the data respecting the phase of maximum obscuration, and the approximate magnetic elements, as applying to the solar eclipse of August 21, 1914. Unfortunately, in our present list there are no stations within the belt of totality. However, there were several such stations, if the European war did not prevent the carrying out of the various proposed plans. The data from these stations will doubtless be included in the reports and discussions by others. Of our list, Rude Skov, near Copenhagen, Denmark, and Ksara, Syria, were nearest to the totality belt. The degree of obscuration (see Table A) at these stations was nearly 0.9, at the stations in Great Britain, 0.6 to 0.7, and at Ekaterinburg, 0.7.

In accordance with previous experience, a possible eclipse magnetic effect will make itself felt differently according to the position of the station with reference to the belt of totality, the time of day when the maximum phase occurs, the direction of motion of the shadow cone, etc. Generally speaking, the effect is to cause a retardation, or alteration, in the usual course of the magnetic diurnal variation. For the four stations, Eskdalemuir, Stonyhurst, Kew, and Rude Skov, the maximum phase of the eclipse occurred at about the time when the declination needle is approaching its maximum westerly position for the day. Fig. 4 shows the declination changes for these four stations during the period 10^h to 15^h (3 P. M.) Greenwich civil mean time, August 21, 1914. The approximate times of the maximum obscuration are shown on the various curves by a heavy vertical mark.

Examining Fig. 4 it will be seen that a bay occurred at each station a few minutes before the time of maximum obscuration. As the result of this bay, the customary progression towards a

[4] From the table of international "magnetic character numbers" for 1914 (*Terr. Mag.*, vol. 20, p. 137), the following data are extracted for the period during which the particular Sun-spot group here considered was visible:

Date 1914	Mag. Char.	Date 1914	Mag. Char.	Date 1914	Mag. Char.	Date 1914	Mag. Char.	Date 1914	Mag. Char.
Aug. 13	0.4	Aug. 16	0.1	Aug. 19	0.9	Aug. 22	0.1	Aug. 25	0.8
14	0.1	17	0.4	20	0.9	23	1.2	26	0.6
15	0.2	18	0.6	21	0.3	24	0.5		

These numbers show that, on the whole, August 21 was fairly quiet. In fact only about 20 per cent of the magnetic observatories (most of these, too, being outside of the region of visibility of the eclipse) assigned the number 1 (moderately disturbed) to August 21.

Table A.—*Data pertaining to the various stations.*

No.	Station	Country	Geographical Position			Max. Observation			Approx. Mag. El.		
			Lat. *a*	Long. fr. Gr. *b*		Degree *c*	G. M. T.	L. M. T.	D	H	Z *e*
			° ′	° ′	h m		h m	h m	°	cgs	cgs
15	Cheltenham	Maryland	+38 44	− 76 50	− 5 07	About	sun r	ise	6.0W	.195	+.558
13	Agincourt	Canada	+43 47	− 79 16	− 5 17	0.1	10 42	*d*5 25	6.4W	.161	+.588
1	Eskdalemuir	Scotland	+55 19	− 3 12	− 0 13	0.69	12 02	11 50	17.8W	.168	+.452
2	Stonyhurst.	England	+53 51	− 2 28	− 0 10	0.67	12 05	11 55	16.8W	.173	+.445
3	Kew.	England	+51 28	− 0 19	− 0 01	0.64	12 10	12 09	15.5W	.185	+.433
4	Rude Skov. .	Denmark	+55 51	+ 12 27	+ 0 50	0.87	12 18	13 08	8.9W	.173	+.446
5	Ksara	Syria	+33 49	+ 35 53	+ 2 24	0.87	13 22	15 46	0.3W	....	......
6	Ekaterinburg	Russia	+56 50	+ 60 38	+ 4 02	0.69	12 46	16 49	11.0E	.173	+.509
8	Alibag	India	+18 38	+ 72 52	+ 4 52	After	sun-	set	0.7E	.369	+.166
9	Dehra Dun.	India	+30 19	+ 78 03	+ 5 12	After	sun-	set	2.3E	.332	+.325
10	Kodaikanal	India	+10 14	+ 77 28	+ 5 10	After	sun-	set	1.3W	.375	+.028
7	Mauritius .	Mauritius	−20 06	+ 57 33	+ 3 50	Out-	side	zone	9.6W	.232	−.310
11	Lukiapang. .	China	+31 19	+121 02	+ 8 04	Out-	side	zone	3.1W	.331	+.338
12	Antipolo . .	Philippines	+14 36	+121 10	+ 8 05	Out-	side	zone	0.6E	.382	+.112
18	Honolulu.	Hawaii	+21 19	−158 04	−10 32	Out-	side	zone	9.7E	.290	+.239
17	Sitka	Alaska	+57 03	−135 20	− 9 01	Out-	side	zone	30.4E	.156	+.560
16	Tucson.	Arizona	+32 15	−110 50	− 7 23	Out-	side	zone	13.7E	.272	+.459
14	Porto Rico. .	Porto Rico	+18 09	− 65 27	− 4 22	Out-	side	zone	3.0W	.284	+.345
19	Washington.	Dis.Columbia	+38 58	− 77 04	− 5 08	About	sun-	rise	4.5W	.191	+.555
20	Burwell. . . .	Labrador	+60 25	− 64 52	− 4 19	0.5	10.5	6.2	46.0W	.083	+.592
21	Ruwe. . .	Belg'n Congo	−10 41	+ 25 34	− 1 42	Out-	side	zone	12.3W	.252	−.233
22	Dessié	Abyssinia	+11 06	+ 39 35	+ 2 38	0.5	14.2	16.8	1.7W	.350	+.016
23	Canton. . . .	China	+23 06	+113 19	+ 7 33	Out-	side	zone	0.3W	.373	+.234

a North latitude designated by +. *b* East longitude designated by +. *c* Taking diameter of Sun as unit. *d* Sunrise occurred at about 5h 12m L. M. T. *e* North magnetic hemisphere designated as +.

westerly extreme was interrupted, and a retrograde movement occurred which continued for some time. Of the four stations, the bay was most developed at Rude Skov, the nearest one, of the present stations, to the belt of totality. The total range of this minor oscillation was at Rude Skov, about 2′, or the amplitude was 1′, which is the order of magnitude of similar oscillations observed at some previous eclipses.[5]

Fig. 4 would apparently also indicate that the Greenwich mean time of the lowest point of the bay occurred later and later in passing from Eskdalemuir to Rude Skov, and approximately according to the same rate that the phase of maximum obscuration progressed from station to station (see almost parallel course of the two lines passing, respectively, through the lowest points of the bays and through the maximum-obscuration marks). The

[5] See, for example, L. A. Bauer's articles in *Terr. Mag.*, vol. 5, 1900, pp. 143-165, and vol. 7, 1902, pp. 155-192.

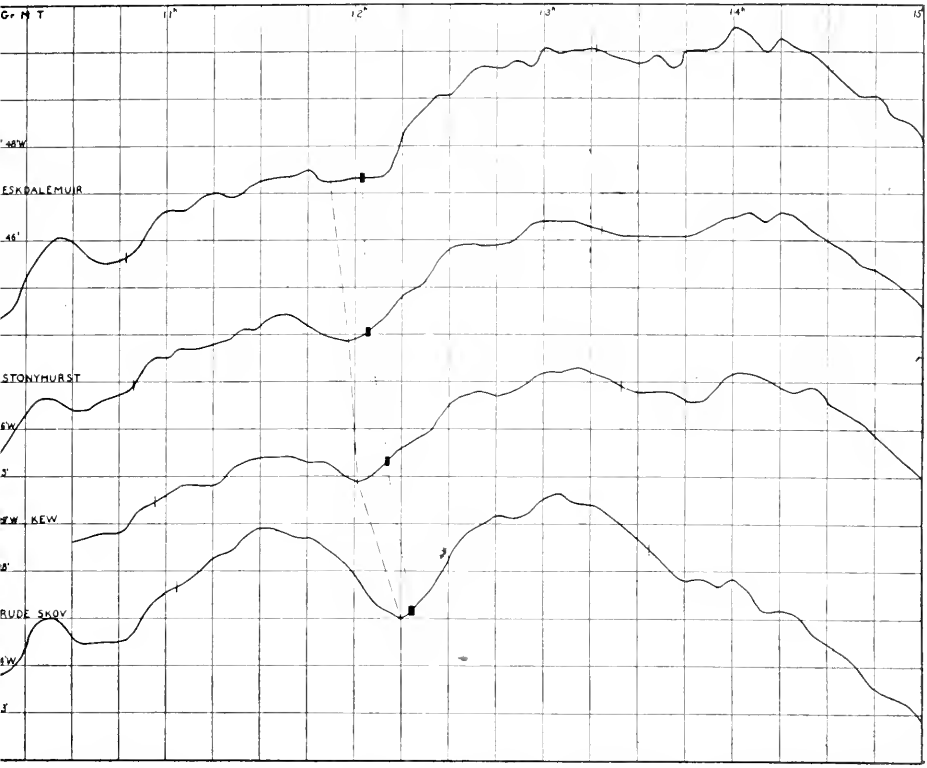


FIG. 4.—Magnetic Declination Changes at Eskdalemuir, Stonyhurst, Kew and Rude Skov, gust 21, 1914.

occurrence of a magnetic effect at various stations, not at the same absolute time nor at the same local time, but related in some manner to the rate of progress of the shadow cone, may have to be regarded as one of the chief characteristics of a possible eclipse effect.[5] This fact serves to differentiate an eclipse magnetic effect from a general, or terrestrial, effect such as might be associated with Sun-spot activity. The approximate times at which the magnetic effect corresponding to the lowest point of the bay occurred are as follows:

TABLE B.

	Magnetic Effect (Decl'n) G. M. T.	Magnetic Effect (Decl'n) L. M. T.	Max. Obscuration G. M. T.	Max. Obscuration L. M. T.
	h m	h m	h m	h m
1. Eskdalemuir,	11 52	11 39	12 02	11 50
2. Stonyhurst,	11 58	11 48	12 05	11 55
3. Kew,	12 01	12 00	12 10	12 09
I. Mean of Nos. 1, 2, 3,	11 57	11 49	12 06	11 58
4. Rude Skov,	12 15	13 05	12 18	13 08
Difference (No I. – No. 4),	– 0 18	– 1 16	– 0 12	– 1 10

It is thus seen that the difference in G. M. T. for the average of the three observatories in Great Britain and the Danish Observatory is 18^m, and that it is in the same direction as the difference in time of the phase of maximum obscuration of the eclipse. The difference in local mean time, as seen, is $1^h\ 16^m$. When data from stations in the totality belt are available, the difference in time of the magnetic effect may be further investigated.

The declination bay shown in Fig. 4 is not found developed in the same manner at the stations outside the zone of visibility of the eclipse.[6] This fact leads to the presumption that it was not an effect due to the disturbance of the magnetic state of the entire Earth, but was more or less restricted approximately to the region in which the eclipse was visible.

Dr. Chree has made the interesting observation that the Kew *D*-curve on August 20, 1914, showed some bays similar to the one at the time of the eclipse on the following day.[7] Some abnormal effects might reasonably be expected on August 20, as it was a more *disturbed* day than August 21, the daily magnetic character numbers being, respectively, 0.9 and 0.3, which fact is confirmed by special information pertaining to the United States magnetic observatories supplied by Superintendent Jones of the Coast and Geodetic Survey. Moreover, it has not been contended that a possible eclipse magnetic effect is distinctly different from an effect which may occur at *any* time. See, for example, the paper in *Terr. Mag.*, vol. 20, pp. 143-158, from which it appears that it is quite possible to have magnetic effects concomitant with solar changes, as revealed by values of the solar constant, having some of the same characteristics as an eclipse magnetic effect. The causes are identical, only the manner of their origin is different. Thus during an eclipse solar radiation is cut off from a portion of the Earth by the intervention of the Moon between the Sun and the Earth. In the other case, we may have solar radiation diminished by a cooling layer in the solar atmosphere. The chief conclusion[8] drawn from our previous investigation was that the eclipse magnetic variation "is analogous in its nature to the solar-diurnal variation, differing from it only in degree."

[6] At Lukiapang, China, there occurred a bay in the declination curve (see Fig. 3) on August 21, but the time of the lowest point is $13^h\ 01^m$ G. M. T., hence about an hour after the mean time of the bay noticed at the four stations enumerated in Table B.

[7] *Terr. Mag.*, vol. 20, p. 72, and Fig. 1.

[8] *Terr. Mag.*, vol. 7, 1902, p. 192.

At Ksara, Syria, where the maximum obscuration (about 0.87) occurred approximately at 3^h 46^m P. M., local mean time, the effect of the eclipse, apparently, was to retard the afternoon declination extreme two hours or more. (See Berloty's account, p. 67.)

The changes in declination at Ekaterinburg, if compared with the bi-hourly data for five quiet days before and after the eclipse (August 14, 15, 16, 17, 18, 22, 24, 25, 26, 27), kindly communicated by Director Abels, would appear to have reached a crest near the time (12^h 46^m G. M. T.) of maximum obscuration. Thus the deflection of the needle towards the east was at 11^h G. M. T., + 1.′4; at 13^h, + 3.′5; and at 15^h, + 1.′0.

There were also apparently some changes in the horizontal and in the vertical intensity during the time of the eclipse, but these can be investigated more successfully when additional data are available. Thus at Kew, the horizontal intensity on August 21, as compared with the values on three preceding and three succeeding quiet days (see Tables 1 and 2, *Terr. Mag.*, vol. 20, pp. 72-73), was about 3γ high at the beginning of the eclipse, near the phase of maximum obscuration it was, on the average, 5γ high and at the end of the eclipse 7γ low.

Fig. 5 gives the *XY* vector diagram at Rude Skov for the period 10^h to 14^h 25^m, G. M. T., as drawn with the aid of the north (X) and west ($-Y$) components, derived from the observed declinations and horizontal intensities. The times of the beginning of the eclipse (B), of the maximum phase (M), and of the ending (E) of the eclipse will be found indicated on the diagram. It will be noticed that during the eclipse the regular course of the curve was interrupted and a loop was described, the point E almost coinciding with B. Similar loops were described at Kew and Eskdalemuir for which vector diagrams have been drawn, though the times of the loops are slightly different than for Rude Skov as they should be if the effect was not terrestrial in its extent. In this connection the reader may be referred, for example, to the formation also of a loop in the vector diagram during the total solar eclipse at Rocky Mount, North Carolina, on May 28, 1900 (*Terr. Mag.*, vol. 5, 1900, p. 157, Fig. 4).

There appears to be good reason for believing that an observable magnetic effect occurred during the time of the solar eclipse of August 21, 1914, at stations within the region of visibility, the effect being larger for stations near the belt of totality than for those

farther away. The subject is of sufficient theoretical importance to merit further careful investigation. A favorable opportunity will occur again in the United States during the total solar eclipse of June 8, 1918.

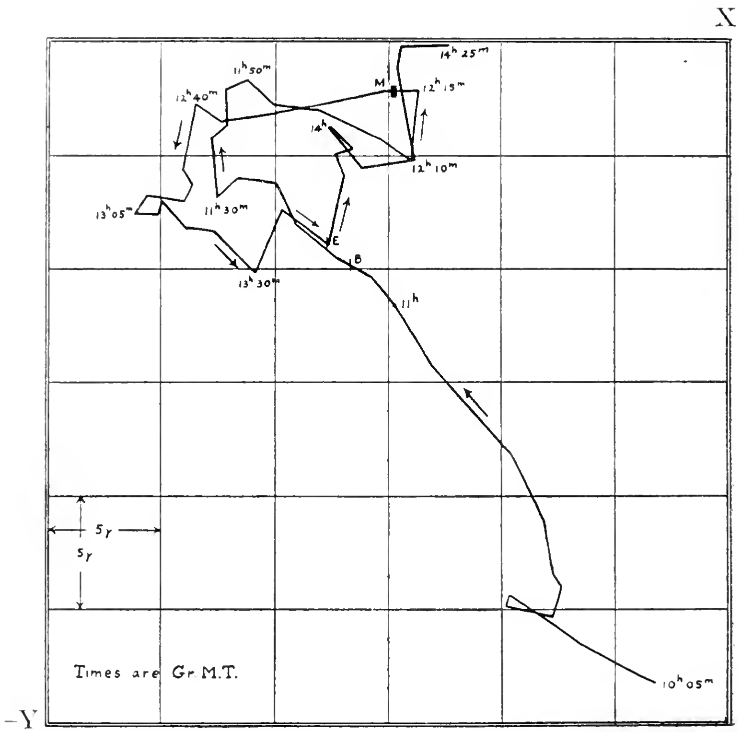


FIG. 5.—XY—Vector Diagram for Rude Skov, August 21, 1914.

INVESTIGATIONS WITH REGARD TO THE EFFECT OF THE INDUCED CHARGE ON THE EBERT ELECTROMETER AT KEW OBSERVATORY.

By E. H. Nichols.

For a normal positive electric field surrounding any earthed body placed above the surface of the ground there is an induced negative charge on the body, increasing with its capacity and the potential gradient. Dr. W. F. G. Swann[1] has attempted to estimate the effect of the induced charge on the Ebert electrometer. According to his reasoning, this decreases the measured ionic density of the negative ions, that of the positive remaining unaffected. He claims that with an air flow of 1.5 liters per second, and a potential gradient of 70 volts per meter, there would be an error of 26 per cent in the values obtained for the negative ions. As the effect is proportional to the strength of the electric field, the errors in measurement for high potentials such as frequently occur in winter would become enormous.

As electrical observations with the Ebert apparatus have been carried out at Kew Observatory for some years, it is important to find out whether these results are affected. For this reason a detailed investigation was carried out in two parts:

1.—The relationship between the recorded electric charges in the air and the potential gradient was examined.

2.—Direct experiments were made with two Ebert electrometers.

Analysis of Kew Data.

The records for a number of years have been analyzed from different points of view. Observations of the positive and negative electric charge per c. c. of air were taken about 3 P. M. on fine days. The values for the potential gradient were obtained from the Kelvin water-dropper apparatus.

a. The values of the negative charge (E_-) were placed in two groups according as the simultaneous potentials were high or low. This process was followed for the available months of 1911, 1912, and 1914. As the observations were very few for some months, February-March, 1912, and August-September, 1912, were considered together. Any induced charge effect being more pronounced for high potentials, smaller values of the negative charge would then be expected. No definite effect is, however, shown (see Table 1).

[1] *Terr. Mag.*, v. 19, p. 205, 1914.

TABLE 1. *Examination of Kew Data.*

	Mean Negative Charge (E_-) at 3 p. m. in E. M. U., 10^{20} for		Ratio of Charges $\frac{E_+}{E_-}$ for		Corresponding Potentials (Volts per Meter) for	
	High Potentials	Low Potentials	High Potentials	Low Potentials	High Values of $\frac{E_+}{E_-}$	Low Values of $\frac{E_+}{E_-}$
1911, May	468	572	1.81	1.34	187	157
June	732	518	0.95	1.50	108	257
July	947	870	1.07	1.26	164	216
Aug.	375	612	2.00	1.47	174	158
Sept.	420	550	1.31	1.50	227	237
Oct.	374	386	1.39	1.21	468	388
Nov.	251	314	1.35	1.50	306	360
Dec.	143	270	2.18	1.13	385	302
Means,	464	512	1.51	1.36	252	259
1912, Jan.	352	207	1.11	1.99	476	495
Feb.-Mar.	293	406	1.58	1.32	243	255
April	796	494	1.30	1.34	209	247
May	939	320	1.08	1.70	78	97
June	916	832	1.00	1.22	121	173
July	691	673	1.22	1.40	149	236
Aug.-Sept.	510	623	1.40	1.14	442	228
Oct.	360	290	1.64	1.73	203	407
Means,	607	481	1.29	1.48	240	267
1914, Jan.	262	167	1.65	1.18	559	476
Feb.	222	371	1.12	0.98	365	380
Mar.	417	492	1.34	0.64	269	224
April	260	577	2.20	1.26	273	202
May	631	369	1.36	1.55	194	205
June	470	566	1.71	1.58	145	168
July	360	469	1.46	1.60	146	171
Aug.	456	442	1.82	1.61	267	246
Sept.	361	604	1.66	1.55	232	211
Oct.	364	299	1.50	1.50	240	342
Nov.	298	312	1.44	1.43	424	436
Dec.	317	318	1.88	1.65	395	347
Means,	368	416	1.60	1.38	292	284
Means for 3 years,	464	461	1.48	1.40	266	272

b. As there are large variations of charge from day to day, it is perhaps better to work with the ratio of the positive and negative charges, which does not vary so much. The ratio of the charges $\frac{E_+}{E_-}$ were computed for the individual months for groups of high and low potential. According to Swann's theory, high potential should increase the ratio. This was, however, found only in 15 out of the

28 months used, while the mean for the three years shows a value five per cent greater for the high potential group. This is very small compared with what one would have expected from Swann's conclusions, as the difference between the means of the high and low potential groups was about 200 volts (Table 1).

c. It was then decided to form the months into two groups of high mean potential and low mean potential, and obtain the ratio of the recorded charges for these months (see Table 2). The low-potential months show a decided tendency to give a lower value of charge ratio, this being apparent in each yearly mean, and is on the average about eight per cent less than for the high-potential months. This result is so far in favor of the theory, but the seasonal factor is probably responsible for part, if not the whole, of the difference.

TABLE 2. *Ratio of Charges* $\frac{E+}{E-}$ *for High- and Low-Potential Months.*

1911	High-Potential Months	Ratio $\frac{E+}{E-}$	Low Potential Months	Ratio $\frac{E+}{E-}$
1911	Sept.,	1.45	May,	1.58
	Oct.,	1.30	June,	1.18
	Nov.,	1.43	July,	1.16
	Dec.,	1.60	Aug.,	1.64
	Mean,	1.45	Mean,	1.39
1912	Jan.,	1.48	April,	1.31
	Feb.-Mar.,	1.44	May,	1.22
	Aug.-Sept.,	1.26	June,	1.11
	Oct.,	1.69	July,	1.30
	Mean,	1.47	Mean,	1.23
1914	Jan.,	1.47	Mar.,	0.91
	Feb.,	1.02	April,	1.55
	Aug.,	1.87	May,	1.45
	Oct.,	1.49	June,	1.63
	Nov.,	1.43	July,	1.54
	Dec.,	1.93	Sept.,	1.60
	Mean,	1.54	Mean,	1.45
Means { 1911, 1912, 1914	(3 years)	1.49	(3 years)	1.37

d. It is more satisfactory to consider the corresponding mean potentials for groups of high and low values, respectively, of the ratio of the charges for the individual months. For eleven months

only out of twenty-eight was the potential for high values of the ratio greater than that for low values. The mean of all the results gives about two per cent lower potential for the group of high ratio of charges. This difference is not merely small, but actually in opposition to Swann's conclusions.

Experiments With Two Ebert Electrometers.

As Swann concludes that there is error only when the induced charge on the outside of the instrument has the same sign as the ions being collected, the error could be avoided when collecting negative ions by giving the outer surface a positive charge. This can be done by insulating the outer cylinder and connecting it to

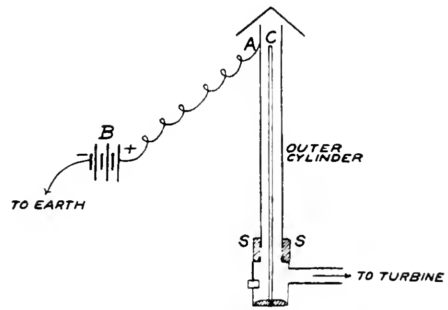


Fig. 1.—Diagram showing Modification of Ebert Electrometer in order to investigate Effect of Induced Charge.

the positive pole of a battery. If sufficient battery power had been available, several hundred volts would have been tried, connecting up alternately the positive and negative poles so as to diminish and increase the error. The largest battery power that could be used was, unfortunately, only fifty volts, but it seemed adequate to test Swann's conclusions provided a considerable number of observations were taken.

The exact arrangement adopted is shown in Fig. 1. The outer cylinder of one instrument was insulated by means of a closely-fitting sulphur block *SS*. A wire leads from the top of the cylinder *A* to the + pole of the battery *B*, the − pole being earthed. The sulphur was carefully moulded so as to prevent inflow of air at this connection, and to preserve the concentricity of the outer cylinder with the inner rod *C*. In this manner the negative induced charge on the cylinder is partially neutralized and the negative charge observed per c.c. of air should thus, according to Swann, be greater than for the cylinder earthed, giving a more correct value. The

two instruments were observed with simultaneously, one having the outer cylinder earthed continuously, the other with the outer cylinder alternately charged to +50 volts and earthed (see Table 3).

TABLE 3. *Scheme of Experiments.*

Old Instrument	Difference of Readings (representing loss of charge on inner rod)	New Instrument	Difference of Readings
Outer Cylinder, + 50 volts	*A*	*Outer Cylinder,* Earthed	*D*
Earthed	*B*	Earthed	*E*
+ 50 volts	*C*	Earthed	*F*

In the case of *B*, the outer cylinder was earthed by disconnecting the wire from battery *B* and leading straight to earth, the sulphur still remaining in position. As the two readings *B* and *E* do not quite agree, there is an instrumental correction to be applied. Allowing for this and comparing the charges obtained from the readings $A + C$ and $D + F$, the effect of the electric field can be estimated. As a further precaution, a series of experiments were made with the instruments interchanged, the outer cylinder of the new instrument being in this case periodically insulated.

TABLE 4. *Experiments Regarding the Induced Charge on the Ebert Electrometer; Values Obtained for the Negative Charge per c. c. of Air in E. M. U.,* $\times 10^{20}$.

Instrument		Old	New	Old	New
Series	No. of Observations	Outer Cylinder + 50 volts	Outer Cylinder Earthed	Earthed	Earthed
1	9	207	184	276	244
2	10	165	117	194	144
3	12	244	238	303	268
Instrument		**New**	**Old**	**New**	**Old**
Series	**No. of Observations**	**Outer Cylinder + 50 volts**	**Earthed**	**Earthed**	**Earthed**
4	8	195	208	212	221

Correcting the above results for instrumental difference, we obtain finally the quantities in Table 5.

TABLE 5. *Results of Experiments.*

Series	Negative charge per c. c. in *E. M. U.*, $\times 10^{20}$	
	Outer Cylinder + 50 volts	Outer Cylinder Earthed
1	207	208
2	165	158
3	244	269
4	195	199
Means,	203	209

To illustrate the method of instrumental correction we may take Series 1. The value obtained for the new instrument = 184 and is multiplied by the factor 276/244 in order to make allowance for the lower reading of the new instrument.

The mean value obtained is three per cent higher when outer cylinder is earthed than when charged to +50 volts. The difference is not too large to be ascribed to experimental error, but much too small to be reconciled with Dr. Swann's conclusions.

POTENTIAL DISTRIBUTION NEAR ELECTROMETER.

As none of the above Kew results support the theory advanced, it was decided to investigate the subject further. It may be well to state the exact position of the Ebert instrument on the observation site. It is placed on a stone pillar of height 120 cm., and cross section 40 × 50 cm., the height of the instrument itself being 70 cm. The instrument is thus at an average height of 1.5 meters above ground level. Other factors which will be considered are the potential distribution near the instrument, the effect of wind velocity, the suction of the turbine, and the effect of the cap on the outer cylinder.

The potential at various points in a vertical plane passing east and west through the central rod of the cylinder of the electrometer was measured by means of a lead nitrate fuse attached to a bamboo rod with a wire leading to a Kelvin portable electrometer.

Readings of potential were taken at heights from the ground of 130, 140, 150 to 220 cm. At each height the bamboo rod was placed carefully in six positions so that the distances of the fuse from the central rod were 5, 15, 25, 35, 45, 55 cm., and the potentials observed. Over fifty different readings were obtained as quickly as possible, in order that the correction for change of potential with time should be small. The actual results of a set of observations are shown in Fig. 2, and indicate the steepness of

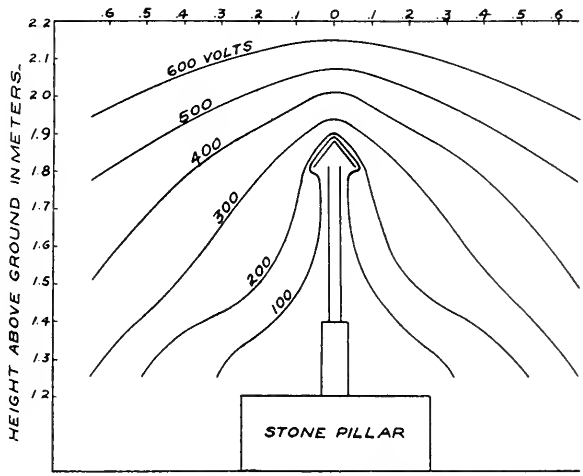


Fig. 2.—Equipotential Lines in neighborhood of the Ebert Electrometer (from observation).

the gradient near the instrument, and also the slope of the equipotential lines (and surfaces). The results were corroborated by a second set of observations. As the gradient is abnormally steep near the cap, it was desirable to explore the field as carefully as possible. This is very difficult, as a small movement of the bamboo rod causes large fluctuations in the voltage measured. The results show that under the cap near the outer cylinder there is a gradient of the order of 50 volts per cm.

Observations of potential were also made at 130 cm. above the ground in the same vertical plane as before at every 10 cm. from the stone pillar along a horizontal line for nearly three meters. The potential recorded shows that the effect of the pillar and instrument in distorting the equipotential surfaces practically disappears at two meters from the edge of the pillar.

WIND VELOCITY NEAR INSTRUMENT.

The effect of wind velocity as regards this problem of induced charge has not been considered by Swann, although the effect is discussed with regard to the instrument on the tower[2], and for the Potsdam conductivity apparatus[3]. It is obvious that with greater wind velocity the negative ions will have more chance of overcoming the repulsive effect of the negative induced charge on the instrument, and entering the cylinder.

[2] *Terr. Mag.*, v. 19, p. 215, 1914.
[3] *Terr. Mag.*, v. 19, p. 35, 1914.

Observations of the wind velocity were made with a small portable Negretti and Zambra air-meter. Readings were obtained with the air-meter on the stone pillar at 35 cm. above the top of the pillar (or mean height of the Ebert electrometer) and at 70 cm. above. This was done on a number of days so as to obtain a good average value for winds of different strengths. There was little difference in value for the different heights, but a general tendency to increase with height. The mean wind velocity for the three heights has been used in the results, and compared with the synchronous value for the Dines anemometer of the Observatory.

Mean Wind Velocity (meters per second).

From Air-meter (1.5 m. above ground near stone pillar)	From Dines' Anemometer (20 m. above ground)
1.7	5.0
1.5	4.7
0.8	2.4
2.3	4.5
2.6	6.2
0.9	1.6
Mean, 1.6	Mean, 4.1

As the mean annual wind velocity for the Dines instrument at the time of electrical observations (3 P. M.) is about 4.5 m. p. s., the average wind velocity just above the stone pillar may be taken as 2 m. p. s.

It can easily be proven that there is no difficulty for the negative ions to approach within 3 or 4 cms. of the outer cylinder. For, the diagram of equipotential lines shows that the gradient quite close to the cylinder is about 10 volts per cm. Now the mean ionic mobility at Kew is roughly 0.5 cm. per second, so that the velocity of repulsion from the outer cylinder due to the induced charge is 0.05 meters per second, which is very small compared with the wind velocity of 2 m. p. s.

We have not considered yet the question of the cap over the cylinder. It is obvious from the equipotential curves that the gradient just above the cap must be abnormally steep, probably 200-300 volts per cm., so that negative ions would naturally be repelled to some extent and deflected toward other points.

For some reason Dr. Swann has not dealt with the question of the cap. According to its specification, the Ebert instrument should always be provided with a metal cap, and those used at Kew Observatory are so provided. In the mathematical treatment given by Swann, the function of the cap seems, however, altogether ignored. Presumably, a rigorous discussion of the question showing the effect of the cap in modifying the form of the equipotential surfaces is beyond the powers of mathematicians at present.

The very steep gradient above the cap does not, however, affect the flow of ions into the cylinder. An experiment was made with smoke in order to find the general form of the stream lines of air near the cylinder under the action of the turbine. No trace of movement in the air could be observed above the cap, but a strong upward motion just underneath. The air stream lines correspond to the equipotential lines found near cylinder. This is an important result, for it implies no diminution in the velocity of the negative ions, as the repulsive force is acting at right angles to the stream lines.

It is clear that the negative ions approach freely quite close to the cylinder. The question is, can they overcome the gradient near the entrance to the cylinder? The gradient here is of the order of 50 volts per cm. The equipotential lines near the cap can be taken as of the form indicated in Fig. 3 (*a*). The line *AB* is the

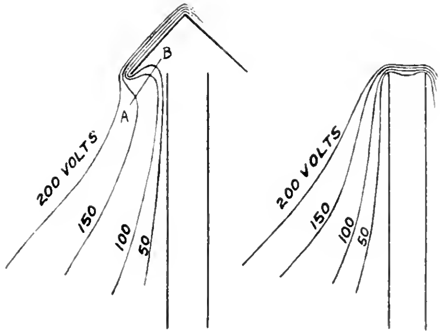


Fig. 3a. Fig. 3b.
Form of Equipotential Lines near Outer Cylinder of Ebert Electrometer.

average direction of motion of the air. The air movement is produced partly by the wind velocity and partly by the suction of the turbine. The wind approaching the surface of the cap, which is at an angle of 45° to the horizontal, is deflected in that direction, near cap, and the velocity will approximate to $2 \sin 45° = 1.4$ m. p. s., taking the horizontal wind velocity as 2 m. p. s. This is too high an estimate, as the form of the cap prevents the free motion of the air underneath. Supposing the velocity to be reduced by one half owing to friction, we obtain 0.7 m. p. s. To this must be added the velocity due to the suction of the turbine (for one direction). In the usual form of apparatus, 1.5 liters pass through the cylinder in 1 second. This gives a velocity of air in the cylinder as 2 m. p. s. The cross-sectional area of base of cap open to air is about 17 times the cross-section of the cylinder, so that the velocity of the air at base of cap due to the suction of turbine is about 0.1 m. p. s. There is thus an air velocity of at least 0.8 m. p. s. if the results may be considered additive for one direction. With a gradient of 50 volts per cm., the velocity of repulsion of the negative ions along BA [see Fig. 3(a)] is only 0.25 m. p. s., so that the negative ions will easily be carried into the cylinder.

If we consider the case of the cap removed from the cylinder, Dr. Swann's reasoning seems sound. The reduction in the number of negative ions collected may be explained by the fact that the air passes through the abnormally steep gradient near the entrance to the cylinder, when unprovided with a cap (see Fig. 3b); it is of the order of 300 volts per cm. just at the entrance. This will give a vertical velocity of 1.5 m. p. s. to the negative ions, assuming the mobility 0.5 cm./sec.

As the air velocity in the cylinder is only 2 m. p. s., the negative ions will be drawn into the cylinder with difficulty. The horizontal wind velocity does not in this case produce any component to assist the air flow in the cylinder.

In order to test the accuracy of the reasoning regarding the effect of the cap, observations were made with two Ebert electrometers, one with its cap on and the other with its cap removed. Precautions were taken to avoid instrumental error as in the previous experiments described. In the first two series of experiments, the old instrument was used with cap off and on, alternately; in the other two series, the new instrument was so used. In each series there are from six to twelve observations, the series occupy-

ing about four hours. The results appear sufficiently conclusive. They show a decrease in the negative charge recorded owing to the removal of the cap, the four series giving respectively reductions of 8, 28, 40, 30 per cent, with a mean of 27 per cent.

TABLE 6. *To Find the Effect of the Cap of the Ebert Electrometer.*

Old Instrument		New Instrument		Percentage of Decrease
Cap	Recorded Negative Charge	Cap	Recorded Negative Charge	
	E. M. U., $\times 10^{20}$		E. M. U., $\times 10^{20}$	
On	235	On	189	$100\left[1-\frac{194\times189}{235\times167}\right]$
Off	194	On	167	$= 7$
On	227	On	201	$100\left[1-\frac{159\times201}{227\times194}\right]$
Off	159	On	194	$= 28$
On	201	On	216	40
On	268	Off	173	
On	183	On	157	30
On	219	Off	131	

SUMMARY.

Dr. Swann's conclusion as to the decrease in the negative charge recorded in the Ebert electrometer has been examined from various points of view.

1. By a consideration of the Kew data for a number of years, the relative effect of high and low potential on the negative charge recorded was not apparent, as it should have been to support the above conclusion.

2. Experiments were made with two Ebert electrometers to find the effect on the recorded negative charge of neutralizing to some extent the induced charge on the instrument by means of a battery. No appreciable effect was observed.

3. Various experiments were carried out in order to investigate the subject more closely.

a. The equipotential lines near electrometer were obtained directly.

b. The wind velocity near instrument was found by using an air-meter.

c. The stream lines of air motion near instrument were obtained approximately by using smoke.

d. Experiments made with and without cap of electrometer show the importance of taking observations with cap in position, and that when cap was removed a mean decrease of 27 per cent was obtained in the negative charge recorded.

4. The results show that with the instrument used in the manner intended by the designer, that is, with the cap in position, the recorded negative charge should not be affected by the induced charge on the instrument, except perhaps in calm weather or with very high potential, which would modify the above reasoning. The experimental evidence indicates that there is a considerable decrease in the negative charge recorded when the metal cap is not used, the condition to which Dr. Swann's mathematical theory seems really to apply.

NOTE.

(*Added April* 5, 1916.)

Dr. Swann has kindly favored me with an advance proof of his reply to my paper, and I desire to thank him for his generous criticism. With regard to the calculation of the error in the negative charge, as given by his formula[4]:

$$\frac{\triangle N}{N} = \frac{4\pi Q v}{\text{Flow of air per c. c.}}$$

It should be noticed that although the value which I had assigned to the mobility at Kew ($v = 0.5$) is only one third of the value assumed by Dr. Swann, the induced charge (Q) would be about three times Dr. Swann's value owing to the high potential at Kew. It would thus seem that the close agreement between the errors of 26 per cent obtained by Dr. Swann and that of 27 per cent obtained at Kew is not merely a coincidence.

My reasoning applies only to the vertical type of Ebert electrometer, which seems now to be in general use[5], and is the only type that has been used at Kew and Eskdalemuir. The horizontal type appears to be the earlier instrument, and was used by Dr. G. C. Simpson at Karasjok (1904).[6]

[4] *Terr. Mag.* 1914, p. 207.

[5] SIMPSON, *Proc. Roy. Soc.*, A85, 1911, p. 188; GOCKEL, *Luft elektrizität*, p. 20.

[6] *Phil. Trans.*, A205, 1906, p. 95.

My object was not to criticise Dr. Swann's general theory, but to show that the type of Ebert electrometer in operation at Kew Observatory does not suffer appreciably from a defect, which I think most readers of Dr. Swann's previous papers would suppose him to refer to all forms of the instrument.

It would be interesting to know exactly what are Dr. Swann's conclusions resulting from his theory applied to the case of vertical type of instrument provided with a cap. There does not appear to be in his reply any clear statement on this point. Dr. Swann raises a number of further issues, but unfortunately I have no opportunity to consider these at present, nor to carry out the experiment he suggests.

REPLY TO E. H. NICHOLS'S ARTICLE (INVESTIGATIONS WITH REGARD TO THE INDUCED CHARGE ON THE EBERT ELECTROMETER AT KEW OBSERVATORY).

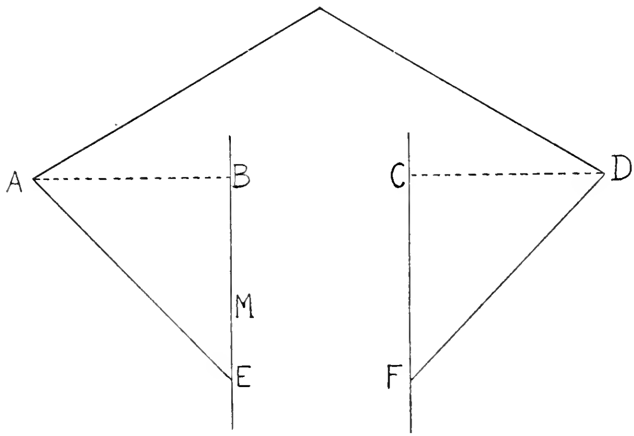
By W. F. G. Swann.

I have read, with very great interest, Mr. Nichols's valuable communication on the Ebert electrometer, and in reply thereto I would first point out that my expression for the correction shows it to be proportional to the specific velocity of the ion, and it will be observed that I used a value 1.5 cm. per second per volt per cm. for this quantity. If I had used the somewhat low value 0.5 cm. per second per volt per cm. which Mr. Nichols takes as the appropriate value for Kew (see p. 94 of his paper), I should have calculated for the correction in the particular example which I took the value 8.7 per cent instead of 26 per cent. I would not by any means suggest, however, that it is impossible to obtain a result even nearer to the truth than 8.7 per cent; the main object of the part of my paper dealing with this matter was to point out the salient features on which the error depends, and to deduce a mathematical expression for the percentage error in *terms of quantities which could be measured comparatively easily.*

Referring now to the points at issue, let me first deal with Mr. Nichols's criticism as to the generality of my theory of the matter.

An examination of my paper will show that I do not, as Mr. Nichols states on page 94 of his paper, ignore the wind. U is defined merely as the component velocity perpendicular to the plane of the opening. The mathematical work in the appendix, and upon

which the paper is largely based, is true for the most general type of air motion. Neither is my formula restricted to a cylindrical opening (as Mr. Nichols states on p. 96 of his paper), nor to a case where the cap is absent (as he says on p. 98). It applies to any sort of opening, as indeed I stated in my paper (*Terr. Mag.*, v. 19, 1914, lines 10-15, p. 207). The only requirement for the strict applicability of the formula, even when the cap is present, is that the air shall enter the mouth at all points. The special case where air enters at one place and leaves at another, without passing down the tube, requires some reservations which I will not here discuss in detail. For practical purposes, in the case of



the cap, the opening may be considered as that represented in section by the lines AB, DC, and Q may be taken as the total charge on the parts of the apparatus above this plane.[1] I should like to suggest that Mr. Nichols try this method of determining the error with the cap present.

Turning now to the relation between Mr. Nichols's experiments and my theory, it should be noticed that my formula does not profess to give the error wholly in terms of more or less universal phys-

[1] One might be inclined to ask why he should not take as the bounding surface a surface such as is indicated in section by the lines AE and DF, and which would inclose also some charge on portions of the tube such as M. Strictly, one *should* take such a boundary surface, not necessarily a symmetrical one, and it is not difficult to see that the position of its intersection at the lower end with the tube is, at each point, determined by the condition that for the applicability of the expression found for the correction, the component velocity of the air in the direction of the inwardly drawn normal to the surface at that point must be greater than that due to the electrical force normal to the surface there. In practice, however, if there is any appreciable wind it is easy to see that we should be sensibly correct in choosing the dotted surface. I will not enter more elaborately into this matter; I only wish to show that it has not been forgotten.

ical constants (like specific ionic velocity, etc.); the quantity Q occurring in the formula has to be determined experimentally for the particular apparatus used. It is primarily a function of the shape of the opening, and before one can say what error my theory predicts for any particular apparatus he must make a direct experiment with the apparatus concerned. Thus Mr. Nichols's results are in no way a disproof of my theory.

My own experiments were made simply for illustration. I naturally chose a condition which would show the effect well, and the end of the tube was not covered with a cap, for it is to be noticed that in the horizontal type of Ebert apparatus, which is the type depicted in nearly all the books[2], and with which presumably much work has been done, there is no cap. As far as I have been able to gather (see Gockel's "*Die Luft-elektrizitaet,*" p. 22, note 3) the cap was added not so much for *electrical reasons as to keep foreign matter out of the apparatus.* I may further remark that as late as 1909, which is certainly later than the time when the capped form was produced, a new horizontal type, with no cap, was brought out by Lutz, and advertised by the firm of M. Th. Edelmann[3].

Although I had no intention whatever of leveling any criticism at the Kew data, nevertheless, in view of the acknowledged importance of these data, I now regret that I did not make a special point of making, and including in my paper, tests on the form of instrument used at Kew, and am prepared to admit that the statement at the bottom of page 208 of my paper, "Now the apparatus as used, etc.," might have been given a tone of less universal applicability.

The whole action of the induced charge in affecting the phenomena is rather subtle, and is, I think, not of the nature which Mr. Nichols considers it to be in his quasi-qualitative discussion of this matter on pages 90–92 of his paper. It is not merely a question of whether or not the field is sufficiently strong to prevent an ion from getting into the mouth of the apparatus, but rather as to the *rate* at which the ions enter. The field causes the ions to enter with a velocity smaller than that of the air, and so reduces the number entering per second.

[2] See, for example, "*Die Atmosphärische Elektrizität,*" by H. MACHE and E. v. SCHWEIDLER; "*Luftelecktrizität,*" by K. KAEHLER (1913); Article by A. Nippoldt on "*Terrestrial Electricity*" from "Mueller-Pouillets' Lehrbuch der Physik" (1914).

[3] Eine neue Form des Ebertschen Aspirations-Apparates, von C. W. LUTZ. Muenchen, *Sitz. Ber. Ak. Wiss.*, 14 Abh., Jahrg. 1909.

Mr. Nichols's use of the velocity 80 cm. per second on page 96 of his paper seems to imply, implicitly, that the wind blows for the most part right under the cap at one side, over the top of the main tube, and out of the cap at the other side. It seems difficult to imagine that there can be very much effect of this kind; but even admitting that there is, and taking Mr. Nichols's own figures, I am unable to see how he can avoid the following conclusions:

The field under the cap, near the outer cylinder, is, according to Mr. Nichols, of an order of magnitude of 50 volts per cm. Supposing the average field over the cross section of the in-flowing air to be no more than 25 volts per cm. and the specific ionic velocity as low as that given by Mr. Nichols (0.5 cm. per second per volt per cm.), we find that the average velocity due to the field is $25 \times 0.5 = 12.5$ cm. per second. The average velocity of the in-flowing air is, according to Mr. Nichols, 80 cm. per second, hence, as a result, one would expect an error of $100 \times 12.5/80 = 15.6$ per cent in the rate of ionic influx. This assumes that the ionic *density* in the in-flowing air is not altered by the field; I take it, however, from the nature of Mr. Nichols's contentions, that he would not criticise this point. Strictly, it requires proof, but it is true, and the proof is given in my paper (l. c., p. 218).

It thus appears that even in the case where the cap is present, Mr. Nichols's conclusions with regard to the error as obtained from a direct comparison of the observations are not in accord with those which naturally evolve from his other experiments. However, the object of my present communication is not to maintain that there is an error in the Kew apparatus, since my formula says nothing about the numerical magnitude of the error until the quantity Q, as experimentally determined for the apparatus, is substituted in it. I am interested to notice, however, that Mr. Nichols's conclusions with regard to the error when there is no cap agree with mine, and that his experiments indicate errors as high as 40 per cent. A phenomenon which can give rise to an error of this magnitude in a form of instrument which has been used by many eminent investigators, is not one which can be lightly disregarded without test in a slightly modified instrument, especially when the modification was probably introduced without relation to the error in question; and I think the chief value of Mr. Nichols's experiments lies in the extent to which they show the cap of the instrument to be an important factor from an electrical standpoint as distinct from its function of keeping out foreign matter.

LETTER TO EDITOR

CRUISE OF THE *CARNEGIE* FROM SOUTH GEORGIA TO LYTTELTON, NEW ZEALAND, JANUARY 14 TO APRIL 1, 1916.[1]

I beg to transmit the following report of our trip from South Georgia to Lyttelton:

The *Carnegie* left South Georgia at 7 P. M., January 14, 1916, towed out of harbor against a heavy head wind by the steam whaler *Fortuna*. In the days that followed we realized that we were in climatic conditions quite different from what we had previously experienced. Icebergs appeared in increasing numbers, and fog was almost continuous. We will long remember January 18 as the only day during the entire trip of four months when we failed to obtain observations for the magnetic declination. The sun was visible for only three seconds during the entire day, giving no opportunity for observations.

Larger icebergs were seen as we neared Lindsay Island, one looming up through the fog like a vast extent of dark land with the bright ice blink reflected from the fog above it. We encountered an ice stream where small pieces were too numerous to dodge.

On January 22 we passed along the north coast of Lindsay Island about three miles off shore, obtaining a good view of this lonely, desolate place, with its deep mantle of snow and ice, surrounded with the wrecked icebergs that have come to grief on its shoals. A delegation of six penguins came out to greet us, the only ones seen in this vicinity.

The island agrees almost exactly in appearance and outline with the description and sketch given in the British Admiralty's Africa Pilot, Part II, 1910. It was surveyed by the German Deep Sea Expedition of 1898 in the *Valdivia*. They gave the position for its center as latitude 54° 26′ S., longitude 3° 24′ E. Our observations place its center in latitude 54° 29′ S., longitude 3° 27′ E., or about 3 miles from the position assigned by the *Valdivia*. This is a very close check in position for these regions, and we had no difficulty in locating the island. When our reckoning had placed it about ten miles southeast of the vessel, we were able to locate it in the proper direction by noting the outline of a snow-covered glacier which appeared motionless through the shifting rifts in cloud and fog.

Some authorities have called this island "Bouvet Island," thereby causing a little confusion. H. R. Mill in his book "The Siege of the South Pole," 1905, gives a couple of pages to a description and picture of Lindsay Island, but names it "Bouvet," and gives as its position the

[1] See *Terr. Mag.* vol. 21, pp. 26-27 for an account of the portion of the cruise from Lyttelton to South Georgia.

latitude and longitude quoted above from the British Admiralty Pilot as that of Lindsay. Both books give as their authority the German Deep Sea Expedition of 1898. The British Admiralty Pilot states that "In November, 1898, the island (Bouvet) was searched for unsuccessfully by Captain Krech, of the German Deep Sea Expedition vessel *Valdivia.* Its position must, therefore, be considered uncertain." We agree with this conclusion since we check so well the position given by the *Valdivia* to Lindsay Island.

Stieler's Hand-Atlas, 1907, publishes a map of Bouvet in a small insert with its south polar charts. The position given, the coast outline, and appearance are those of Lindsay Island.

Did Captains Bouvet and Norris see Lindsay Island or some island that has never been seen again? They reported it, Captain Bouvet in 1739 and Captain Norris in 1825, and placed it in latitude 54° 00′ S. to 54° 15′ S. and in longitude 4° 30′ E. to 5° 00′ E., or about 15 miles north and about 50 miles east of Lindsay. We know that this position is seriously in error, for Cook, Ross and Moore searched unsuccessfully for this island while on their various cruises into the Antarctic.

After taking bearings of Lindsay Island and such pictures as the weather and clouds permitted, we stood east in the hope of sighting Bouvet Island. Unfortunately drifting ice, though in small pieces, became so thick that we thought it best to change our course to the north to avoid delay in this locality. So disappeared our chance of sighting either Bouvet or Thompson Islands.

Shortly after leaving the vicinity of Lindsay Island, it was decided to stand northward toward the Crozet Islands, so as to cut the isogonic lines at a greater angle.

When within 30 miles of the southwest point of Kerguelen Islands, the weather became unfavorable for making the land, fog set in and a gale began to blow, with a rapidly falling barometer. The vessel was immediately headed south to avoid outlying dangers and when clear, the course was set toward Heard Island. The season was advancing, and as a large area remained to be covered before our return to Port Lyttelton, a delay of a week or more in order to land at Kerguelen seemed unwarranted. This was February 6, and in the evening a copper box, tightly sealed, containing abstracts of all results to date, was set adrift on a float. The following was stamped on the copper box with steel dies: "Mail to the Carnegie Institution, Washington, D. C., U. S. A., from Yacht *Carnegie*, February 6, 1916." The float was set adrift at 8 P. M. in latitude 50° 14′.3 S., longitude 68° 19′.2 E. The only sign of human kind seen during four months, except at South Georgia, was a corpse floating in the open sea, about half way between Heard and Kerguelen Islands, far from land. This was on February 7th at latitude 51° 12′ S., longitude 71° 26′ E.

On February 8 our course was set to the northward to intersect the *Carnegie's* track of 1911 and determine the annual change of the magnetic elements. We made the first intersection in good time, but encountered head winds and later a calm when attempting to make the

second crossing. With the aid of the engine, however, we were able to make the desired point.

The annual change determined amounted to 17′ in declination, increasing westerly, as opposed to 8′ shown on the charts; —0°.04 in inclination and —0.0007 C. G. S. units in horizontal intensity.

The brief rest in quiet seas and in warm sunshine was very welcome, but the season was advancing and we must turn southward again and plunge into the dark and stormy regions of the "roaring forties and furious fifties." The stormiest period of the trip awaited us. The heaviest gales and roughest seas yet encountered were experienced, but the vessel stood the strain well.

We were astonished as the *Carnegie* proceeded south toward the region of Queen Mary Land to find the chart errors in declination constantly increasing until, in the region of latitude 60° S., longitude 110° E., they reached a maximum of —12° for the United States and British charts, and of —16° for the German charts.

On March 23, during magnetic observations in the afternoon, the horizontal intensity ranged from .098 to .110 C. G. S., indicating a magnetic disturbance of some kind, possibly a region of local disturbance.

One iceberg was seen on March 1, the only one encountered since January 28. Owing to the decrease in horizontal intensity and the consequent uncertainty of the compasses, it was decided to turn to the northward on this date, latitude 59° 24′ S. having been reached A few hours before the time set for turning northward a south wind sprang up, so it was well that we had planned to continue no farther in that direction.

The portion of our route extending into the Australian Bight was accomplished without special difficulty, and the latitude of 39° 29′ S. was reached.

Going south again the *Carnegie* sailed as far as latitude 57° 25′ S., obtaining the lowest horizontal intensity that we had yet observed at sea, 0.086 C. G. S. units.

Owing to conditions of weather and lateness of season, it was thought best to head directly for Port Lyttelton, taking into consideration the fact that we would intersect at good angles all isomagnetic lines on the way.

The Snares were sighted early on the morning of March 29. They were almost exactly where we expected to see them, so we knew that our chronometers were giving us almost correct longitudes, after four months of hard usage and with the wide range in temperature obtained in the cabin on account of the presence of the heating stove.

Observations for intensity and inclination were taken every day regardless of conditions, even when the vessel was hove to in a hurricane and was being tossed about like a chip, and mountainous seas were threatening to break through the observing domes. Magnetic declinations were observed on all but one day, during the four months' cruise—a remarkable record, considering the prevailing conditions of

fog, mist, rain, and snow. This record was made possible only by the constant watchfulness of the entire party and by taking advantage of every opportunity. Considerable time was spent in "standing by," waiting for a break in the clouds or fog. Frequently only a small opening in the clouds would be seen approaching the Sun, then the vessel would be directed to the proper heading and all observers would be called to their stations ready to begin observations the moment the Sun appeared. Often the Sun was not seen again during the day.

I cannot speak too highly of the work done by each and every member of the party, their spirit of co-operation, their unfaltering zeal in the face of most trying conditions.

Gales occurred of force 7 or higher, Beaufort scale, on 52 out of 120 days. On 26 days the gales were very strong, having an estimated force of 9 to 11. We were overtaken by a continual procession of circular storms, moving about the south polar continent from west to east, and were invariably caught in the northern semicircle as indicated by the barometer changes. A falling barometer always presaged northerly winds shifting to the northwest and blowing hard. As the barometer began to rise, the wind shifted to southwest, blowing a strong gale if the barometer rose rapidly. The temperature of the sea water was taken every hour during the entire cruise excepting the first few days. The air temperature averaged about 5° C. We had precipitation of some sort, mist, light rain, fog, rain, hail, or snow on 100 days out of the 120 days of the voyage. Fog was recorded on 26 days, and snow 16 days.

We were in the region where icebergs may be encountered for a period of 3½ months, yet saw them on only 24 days, and to the number of only 133, the largest being 5 miles long, and highest being 400 feet high.

Upon the return to Port Lyttelton (April 1), there still remained two tanks of fresh water on board, and potatoes and onions sufficient for three more weeks.

The vessel has suffered no serious damage. The metal fastening of the upper topsail yard broke on January 4, but the yard was successfully lashed to the parral and gave us no further trouble. The bronze rod bob-stay carried away at the forward end on February 24. It was fished up after some difficulty and secured with a dead eye and lanyard. Upon examination in the dry dock the vessel's hull was found absolutely clean and undamaged, only one sheet of copper near the keel requiring renewal.

The total distance run from Lyttelton to Lyttelton was 17,091 miles, giving an everage of 148 miles for 115.5 days.

J. P. AULT,
Master of the Carnegie.

On Board the "*Carnegie*,"
Port Lyttelton, New Zealand, April 6, 1916.

NOTES

10. Chapter No. 15 of the tenth edition Müller-Pouillets Lehrbuch der Physik und Meteorologie (4 ter Band, 5 tes Buch, 1914, pp. 1295-1385), is devoted to the timely topic of the Earth's magnetism (inclusive of the polar lights); it was prepared by the well-known German magnetician, *Dr. A. Nippoldt.* The chapter is divided into 30 sections, comprises 91 pages and contains numerous well-executed plates and text figures. It thus forms a much more comprehensive treatment of terrestrial magnetism than is usually found in text books of physics. It is in fact an up-to-date treatise of sufficient scope to fill satisfactorily the general needs, not only of students, but also of those actively engaged in the subject.

11. Personalia. We regret to record the death of *Dr. William Frederick King* on April 23, in his sixty-second year, for many years director of the Dominion Observatory at Ottawa, Canada; under this institution the magnetic survey of Canada is being conducted. *G. W. Walker* gave a course of lectures on Terrestrial Magnetism at Cambridge University, and also, in place of Prince Galitizin, the Halley lecture at the University of Oxford.

12. Principal Magnetic Storms Recorded at the Cheltenham Magnetic Observatory, January-March, 1916. The following data have been communicated by the Superintendent of the United States Coast and Geodetic Survey.

Latitude 38° 44′.0 N: longitude 76° 50′.5, or 5ʰ 07.4ᵐ W. of Greenwich.

Greenwich Mean Time		Range		
Beginning 1916	Ending 1916	D (Declination)	H (Hor'l Int.)	Z (Vert'l Int.)
h m	h	′	γ	γ
Jan. 10, 20 05	Jan. 13, 5	34.5	193	139
Mar. 8, 0 41	Mar. 10, 2	43.0	225	155
Mar. 17, 0 18	Mar. 17, 13	34.5	193	184
Mar. 29, 6 28	Apr. 1, 8	29.3	207	174

ABSTRACT

DECHEVRENS, M. MARC. *Les Ondes Hertziennes Atmosphériques Enregistrées et Étudiées a L'Observatoire Saint-Louis, Jersey, en 1912 et 1913.*[1]

This paper forms a continuation of the investigations made at Jersey from November 1911 to October 1913. A new instrument, described in the former paper, and which records not only the number but the intensity of the Hertzian disturbances, was employed. Former observations, in which coherers have been used, suggest the idea that the waves arise only as the result of storms; but with the new instrument hardly a day passes without waves being recorded.

The author concludes from an examination of the data that, in addition to the powerful disturbances associated with storms, there are disturbances of a more regular nature, showing a definite diurnal variation, and attributable to other causes. In support of this contention he shows the summer and winter diurnal-variation curves for the waves recorded at Jersey and Tortosa (Spain). In spite of the great variation in climatic conditions between the two stations, and of the fact that the data for Jersey represent the means from November 1911 to October 1913, while those for Tortosa represent the means from January 1910 to July 1912, the curves for the corresponding seasons at the two places show a marked similarity.

The author also calls attention to a striking similarity between the diurnal-variation curves for the Hertzian waves and for the terrestrial-magnetic declination. In conclusion he suggests that just as the powerful waves caused by storms, and which occur comparatively rarely, have their origin in the electrical discharges in the lower atmosphere, so these disturbances corresponding to quiet days are the result of the more frequent electrical discharges in the rarified regions of the upper atmosphere.

W. F. G. S.

[1] Paris, C.—R. ass. franç. avanc. sci., Congrès du Havre, 1914 (314-223).

Terrestrial Magnetism

and

Atmospheric Electricity

VOLUME XXI　　SEPTEMBER, 1916　　NUMBER 3

MAGNETIC DECLINATIONS AND CHART CORRECTIONS OBSERVED ON THE *CARNEGIE* FROM LYTTELTON, NEW ZEALAND, TO SOUTH GEORGIA, AND THENCE TO LYTTELTON AND PAGO PAGO, DECEMBER 1915—JUNE 1916.[1]

BY J. P. AULT, Commanding the *Carnegie*.

(*Observers;* J. P. Ault, H. M. W. Edmonds, I. A. Luke, H. F. Johnston, F. C. Loring, and B. Jones. *Minus indicates west declination, and plus, east declination.*)

Date	Position		Carnegie	Chart Values			Chart Corrections		
	Latitude	Longitude		Brit.[2]	Ger.[3]	U. S.[4]	Brit.	Ger.	U. S.
1915	° ′	° ′	°	°	°	°	°	°	°
Dec. 6	43 47 S	173 20 E	+17.1	+17.1	+17.9	+17.2	0.0	− 0.8	− 0.1
7	46 04 S	174 39 E	+17.9	+18.7	+19.2	+18.6	− 0.8	− 1.3	− 0.7
8	47 37 S	176 16 E	+18.3	+19.6	+20.1	+19.7	− 1.3	− 1.8	− 1.4
9	49 03 S	178 20 E	+18.5	+20.3	+20.9	+20.7	− 1.8	− 2.4	− 2.2
9	49 23 S	179 13 E	+20.4	+20.4	+21.1	+20.9	0.0	− 0.7	− 0.5
9	49 56 S	179 13W	+20.4	+20.7	+21.4	+21.1	− 0.3	− 1.0	− 0.7
9	50 28 S	177 34W	+21.5	+21.0	+21.7	+21.4	+ 0.5	− 0.2	+ 0.1
9	50 34 S	177 17W	+20.9	+21.1	+21.8	+21.5	− 0.2	− 0.9	− 0.6
10	51 29 S	175 47W	+21.3	+21.6	+22.1	+22.0	− 0.3	− 0.8	− 0.7
11	53 03 S	173 42W	+22.4	+22.7	+22.9	+22.9	− 0.3	− 0.5	− 0.5
11	53 34 S	172 43W	+21.5	+23.0	+23.1	+23.3	− 1.5	− 1.6	− 1.8
11	53 51 S	172 16W	+22.0	+23.1	+23.2	+23.5	− 1.1	− 1.2	− 1.5
12	54 18 S	171 42W	+22.1	+23.4	+23.4	+23.8	− 1.3	− 1.3	− 1.7
12	53 44 S	170 13W	+22.3	+22.7	+22.7	+23.3	− 0.4	− 0.4	− 1.0
13	54 12 S	168 50W	+22.6	+22.9	+22.9	+23.6	− 0.3	− 0.3	− 1.0

[1] The narratives of this cruise will be found in *Terr. Mag.*, v. 21, pp. 26-27, 103-106, 1916. For previous tables, see *Terr. Mag.*, v. 15, pp. 57-82, 129-144; v. 16, pp. 133-136; v. 17, pp. 31-32, 97-101, 141-144, 179-180; v. 18, pp. 63-64, 111-112, 161-162; v. 19, pp. 38, 126, 204, 234-235; v. 20, pp. 69-70, 104; v. 21, pp. 15-18.

[2] From British Admirality Chart No. 2598 for 1912 with secular change data applied except in region south of 40° south latitude and between 0° and 100° east longitude.

[3] From Reichs-Marine-Amt Chart Tit. XIV, No. 2 for 1910, with secular change data applied except in region south of 40° south latitude and between 0° and 100° east longitude.

[4] From U. S. Hydrographic Office Chart No. 2406 for 1915, referred, when possible, to 1916.

Date	Position		Carnegie	Chart Values			Chart Corrections		
	Latitude	Longitude		Brit.[2]	Ger.[3]	U. S.[4]	Brit.	Ger.	U. S.
1915	° ′	° ′	°	°	°	°	°	°	°
Dec. 13	54 46 S	167 46 W	+23.3	+24.2	+23.2	+24.0	− 0.9	+ 0.1	− 0.7
14	55 12 S	166 25 W	+22.9	+23.5	+23.3	+24.4	− 0.6	− 0.4	− 1.5
14	55 29 S	164 22 W	+23.5	+23.6	+23.3	+24.6	− 0.1	+ 0.2	− 1.1
14	55 43 S	163 26 W	+23.0	+23.7	+23.3	+24.8	− 0.7	− 0.3	− 1.8
15	56 00 S	162 33 W	+24.3	+23.8	+23.4	+25.1	+ 0.5	+ 0.9	− 0.8
15	56 08 S	161 36 W	+24.0	+23.9	+23.5	+25.3	+ 0.1	+ 0.5	− 1.3
16	57 36 S	157 14 W	+25.7	+24.8	+24.1	+26.6	+ 0.9	+ 1.6	− 0.9
17	58 25 S	155 38 W	+26.8	+25.5	+24.8	+27.2	+ 1.3	+ 2.0	− 0.4
17	59 26 S	153 42 W	+27.0	+26.6	+25.8	+28.1	+ 0.4	+ 1.2	− 1.1
18	60 16 S	151 18 W	+29.5	.....[5]	.....[5]	.....[5]	......	......	......
19	60 18 S	147 18 W	+29.3	.....[5]	.....[5]	.....[5]	......	......	......
19	60 20 S	144 29 W	+30.7	.....[5]	.....[5]	.....[5]	......	......	......
20	60 26 S	141 11 W	+30.6	.....[5]	.....[5]	.....[5]	......	......	......
20	60 32 S	138 52 W	+30.9	.....[5]	.....[5]	.....[5]	......	......	......
21	60 09 S	132 28 W	+30.4	.....[5]	.....[5]	.....[5]	......	......	......
22	59 46 S	129 28 W	+30.9	+28.1	+27.6	+31.0	+ 2.8	+ 3.3	− 0.1
22	59 40 S	128 49 W	+30.8	+28.1	+27.8	+31.1	+ 2.7	+ 3.0	− 0.3
22	59 38 S	127 16 W	+32.0	+28.2	+27.9	+31.5	+ 3.8	+ 4.1	+ 0.5
23	60 32 S	124 04 W	+32.7	.....[5]	.....[5]	.....[5]	......	......	......
24	60 06 S	124 21 W	+32.4	.....[5]	.....[5]	.....[5]	......	......	......
24	59 37 S	123 26 W	+31.6	+28.8	+28.7	+32.4	+ 2.8	+ 2.9	− 0.8
25	59 14 S	118 26 W	+31.7	+29.2	+29.6	+32.3	+ 2.5	+ 2.1	− 0.6
25	59 10 S	115 51 W	+31.7	+29.7	+30.1	+32.2	+ 2.0	+ 1.6	− 0.5
26	59 08 S	112 20 W	+31.4	+30.5	+30.7	+32.2	+ 0.9	+ 0.7	− 0.8
26	59 06 S	109 44 W	+31.3	+31.1	+31.3	+32.1	+ 0.2	0.0	− 0.8
26	59 05 S	108 44 W	+31.6	+31.2	+31.6	+32.0	+ 0.4	0.0	− 0.4
27	59 07 S	105 37 W	+31.9	+31.7	+32.0	+31.7	+ 0.2	− 0.1	+ 0.2
27	59 07 S	102 24 W	+31.0	+31.0	+32.0	+31.1	0.0	− 1.0	− 0.1
27	59 03 S	101 26 W	+30.7	+30.8	+32.0	+30.8	− 0.1	− 1.3	− 0.1
28	58 54 S	99 00 W	+31.0	+30.3	+31.5	+30.1	+ 0.7	− 0.5	+ 0.9
28	58 48 S	95 55 W	+30.4	+29.8	+30.8	+29.4	+ 0.6	− 0.4	+ 1.0
28	58 48 S	94 59 W	+30.2	+29.6	+30.7	+29.3	+ 0.6	− 0.5	+ 0.9
29	58 48 S	92 28 W	+29.1	+29.0	+30.0	+28.7	+ 0.1	− 0.9	+ 0.4
29	58 48 S	90 30 W	+28.8	+28.6	+29.3	+28.1	+ 0.2	− 0.5	+ 0.7
30	58 48 S	89 46 W	+28.6	+28.4	+29.1	+27.9	+ 0.2	− 0.5	+ 0.7
30	58 49 S	87 52 W	+27.8	+27.8	+28.3	+27.4	0.0	− 0.5	+ 0.4
31	58 50 S	86 58 W	+27.9	+27.6	+28.1	+27.2	+ 0.3	− 0.2	+ 0.7
31	59 08 S	84 23 W	+26.8	+26.9	+27.2	+26.6	− 0.1	− 0.4	+ 0.2
1916									
Jan. 1	59 12 S	82 21 W	+25.8	+26.1	+26.3	+26.0	− 0.3	− 0.5	− 0.2
1	59 22 S	79 21 W	+24.7	+25.1	+25.1	+25.3	− 0.4	− 0.4	− 0.6
2	59 58 S	75 29 W	+22.7	+23.7	+23.3	+23.7	− 1.0	− 0.6	− 1.0
2	60 08 S	73 40 W	+22.4	.....[5]	.....[5]	.....[5]	......	......	......
3	59 56 S	70 18 W	+20.4	+21.3	+20.2	+20.7	− 0.9	+ 0.2	− 0.3
3	59 41 S	68 20 W	+18.7	+20.2	+18.9	+19.5	− 1.5	− 0.2	− 0.8
3	59 41 S	67 21 W	+19.1	+19.7	+18.2	+18.9	− 0.6	+ 0.9	+ 0.2
4	59 53 S	65 55 W	+17.8	+18.8	+17.5	+18.0	− 1.0	+ 0.3	− 0.2
5	59 33 S	64 01 W	+16.5	+17.5	+16.4	+16.8	− 1.0	+ 0.1	− 0.3
5	59 12 S	62 06 W	+15.1	+15.7	+15.1	+15.6	− 0.6	0.0	− 0.5
5	59 04 S	61 09 W	+14.2	+14.8	+14.4	+14.8	− 0.6	− 0.2	− 0.6
6	58 47 S	59 18 W	+13.8	+13.4	+13.1	+13.4	+ 0.4	+ 0.7	+ 0.4
7	58 00 S	53 07 W	+ 8.8	+ 9.4	+ 9.1	+ 9.0	− 0.6	− 0.3	− 0.2
7	57 26 S	51 02 W	+ 7.4	+ 7.7	+ 7.5	+ 7.2	− 0.3	− 0.1	+ 0.2
8	56 20 S	46 54 W	+ 3.9	+ 4.1	+ 4.1	+ 4.0	− 0.2	− 0.2	− 0.1

[5] Beyond the chart limits.

Date	Position		Carnegie	Chart Values			Chart Corrections		
	Latitude	Longitude		Brit.[2]	Ger.[3]	U. S.[4]	Brit.	Ger.	U. S.
1916	° ′	° ′	°	°	°	°	°	°	°
Jan. 9	55 35 S	44 42 W	+ 2.4	+ 2.2	+ 2.3	+ 2.3	+ 0.2	+ 0.1	+ 0.1
10	54 18 S	40 43 W	− 1.4	− 1.6	− 1.0	− 1.0	+ 0.2	− 0.4	− 0.4
11	54 09 S	38 23 W	− 3.4	− 3.3	− 2.6	− 2.6	− 0.1	− 0.8	− 0.8
11	53 54 S	38 14 W	− 3.1	− 3.5	− 2.7	− 2.7	+ 0.4	− 0.4	− 0.4
11	53 54 S	37 54 W	− 3.6	− 3.8	− 3.0	− 3.2	+ 0.2	− 0.6	− 0.4
12	54 16 S	36 20 W	− 4.7	− 4.9	− 3.7	− 4.0	+ 0.2	− 1.0	− 0.7
15	54 14 S	34 33 W	− 5.7	− 6.0	− 5.3	− 5.3	+ 0.3	− 0.4	− 0.4
15	54 14 S	33 57 W	− 6.2	− 6.4	− 5.4	− 5.8	+ 0.2	− 0.8	− 0.4
15	54 19 S	31 22 W	− 7.7	− 8.3	− 7.1	− 7.5	+ 0.6	− 0.6	− 0.2
16	54 41 S	27 58 W	−10.6	−10.2	− 9.4	− 9.5	− 0.4	− 1.2	− 1.1
17	54 34 S	25 12 W	−12.1	−12.2	−11.3	−11.3	+ 0.1	− 0.8	− 0.8
19	54 30 S	15 38 W	−17.3	−18.2	−17.0	−17.5	+ 0.9	− 0.3	+ 0.2
19	54 29 S	14 41 W	−17.5	−18.8	−17.4	−18.0	+ 1.3	− 0.1	+ 0.5
20	54 19 S	10 12 W	−20.0	−21.1	−19.7	−20.5	+ 1.1	− 0.3	+ 0.5
20	54 18 S	9 32 W	−20.4	−21.4	−20.1	−20.9	+ 1.0	− 0.3	+ 0.5
20	54 17 S	8 36 W	−20.1	−21.7	−20.5	−21.4	+ 1.6	+ 0.4	+ 1.3
21	53 53 S	1 50 W	−22.8	−24.9	−24.2	−24.4	+ 2.1	+ 1.4	+ 1.6
21	53 45 S	1 23 W	−24.3	−25.2	−24.5	−24.6	+ 0.9	+ 0.2	+ 0.3
22	53 41 S	0 39 E	−25.2	−25.9	−25.3	−25.3	+ 0.7	+ 0.1	+ 0.1
22	54 22 S	2 36 E	−24.7	−26.4	−26.0	−25.7	+ 1.7	+ 1.3	+ 1.0
23	53 48 S	4 19 E	−25.3	−27.2	−27.0	−26.3	+ 1.9	+ 1.7	+ 1.0
23	53 32 S	6 21 E	−26.2	−28.0	−28.1	−27.1	+ 1.8	+ 1.9	+ 0.9
24	53 39 S	9 22 E	−27.1	−29.1	−29.1	−27.9	+ 2.0	+ 2.0	+ 0.8
24	53 47 S	10 54 E	−27.0	−29.5	−29.6	−28.2	+ 2.5	+ 2.6	+ 1.2
25	54 03 S	14 35 E	−28.5	−30.6	−30.6	−29.0	+ 2.1	+ 2.1	+ 0.5
25	54 16 S	16 30 E	−28.4	−31.1	−31.0	−29.4	+ 2.7	+ 2.6	+ 1.0
26	54 33 S	19 55 E	−28.8	−32.0	−31.7	−30.1	+ 3.2	+ 2.9	+ 1.3
26	54 27 S	22 16 E	−29.2	−32.9	−32.2	−30.9	+ 3.7	+ 3.0	+ 1.7
27	54 15 S	26 16 E	−29.6	−34.0	−33.1	−32.1	+ 4.4	+ 3.5	+ 2.5
28	53 56 S	29 43 E	−29.5	−35.0	−33.9	−33.2	+ 5.5	+ 4.4	+ 3.7
28	53 25 S	32 12 E	−29.5	−35.6	−34.4	−33.9	+ 6.1	+ 4.9	+ 4.4
29	52 55 S	34 55 E	−30.6	−35.7	−34.9	−34.8	+ 5.1	+ 4.3	+ 4.2
29	52 51 S	35 19 E	−30.2	−35.7	−35.0	−35.0	+ 5.5	+ 4.8	+ 4.8
30	52 46 S	38 40 E	−31.3	−35.8	−35.8	−35.4	+ 4.5	+ 4.5	+ 4.1
30	52 42 S	39 52 E	−32.0	−35.7	−36.0	−35.4	+ 3.7	+ 4.0	+ 3.4
31	51 53 S	42 33 E	−31.5	−35.1	−36.4	−35.1	+ 3.6	+ 4.9	+ 3.6
31	51 10 S	44 02 E	−31.3	−34.4	−36.4	−34.4	+ 3.1	+ 5.1	+ 3.1
Feb. 1	50 06 S	46 23 E	−30.8	−33.1	−36.3	−33.5	+ 2.3	+ 5.5	+ 2.7
1	49 18 S	48 17 E	−31.0	−32.4	−36.0	−32.9	+ 1.4	+ 5.0	+ 1.9
2	48 36 S	50 00 E	−30.9	−31.7	−35.7	−32.5	+ 0.8	+ 4.8	+ 1.6
2	48 35 S	51 58 E	−31.7	−31.7	−35.8	−32.5	0.0	+ 4.1	+ 0.8
2	48 35 S	52 13 E	−31.8	−31.7	−35.9	−32.5	− 0.1	+ 4.1	+ 0.7
3	48 34 S	54 00 E	−32.1	−31.9	−36.0	−32.6	− 0.2	+ 3.9	+ 0.5
3	48 34 S	56 08 E	−32.5	−32.2	−36.1	−32.9	− 0.3	+ 3.6	+ 0.4
4	48 44 S	60 23 E	−35.0	−33.0	−36.5	−33.9	− 2.0	+ 1.5	− 1.1
4	48 48 S	60 59 E	−35.1	−33.3	−36.8	−34.1	− 1.8	+ 1.7	− 1.0
5	49 00 S	63 29 E	−34.4	−34.2	−36.8	−35.0	− 0.2	+ 2.4	+ 0.6
5	49 05 S	64 35 E	−36.1	−34.6	−36.9	−35.3	− 1.5	+ 0.8	− 0.8
6	49 24 S	66 12 E	−37.7	−35.3	−37.3	−36.0	− 2.4	− 0.4	− 1.7
6	50 09 S	68 01 E	−38.5	−36.3	−38.2	−37.2	− 2.2	− 0.3	− 1.3
7	50 38 S	69 35 E	−39.6	−37.0	−38.9	−37.9	− 2.6	− 0.7	− 1.7
7	51 26 S	72 10 E	−40.6	−38.2	−39.8	−38.9	− 2.4	− 0.8	− 1.7
8	51 42 S	73 22 E	−41.5	−38.6	−40.1	−39.4	− 2.9	− 1.4	− 2.1
8	52 19 S	75 36 E	−43.1	−39.4	−40.6	−40.2	− 3.7	− 2.5	− 2.9

Date	Position		Carnegie	Chart Values			Chart Corrections		
	Latitude	Longitude		Brit.[2]	Ger.[3]	U. S.[4]	Brit.	Ger.	U. S.
1916	° ′	° ′	°	°	°	°	°	°	°
Feb. 8	52 28 S	76 29 E	−41.7	−39.6	−40.9	−40.5	− 2.1	− 0.8	− 1.2
9	51 41 S	77 12 E	−41.5	−39.0	−39.5	−40.0	− 2.5	− 2.0	− 1.5
9	50 28 S	78 38 E	−42.3	−38.0	−37.9	−39.0	− 4.3	− 4.4	− 3.3
10	49 11 S	81 10 E	−40.2	−37.1	−35.6	−38.1	− 3.1	− 4.6	− 2.1
10	49 06 S	81 16 E	−41.9	−37.0	−35.4	−38.0	− 4.9	− 6.5	− 3.9
11	47 38 S	82 58 E	−39.2	−36.1	−33.4	−36.8	− 3.1	− 5.8	− 2.4
11	46 35 S	84 16 E	−38.0	−35.3	−32.0	−35.8	− 2.7	− 6.0	− 2.2
12	44 39 S	85 58 E	−35.9	−33.4	−29.4	−34.0	− 2.5	− 6.5	− 1.9
12	43 32 S	87 02 E	−34.4	−32.1	−27.5	−32.6	− 2.3	− 6.9	− 1.8
13	41 47 S	88 12 E	−30.8	−30.1	−25.1	−30.6	− 0.7	− 5.7	− 0.2
13	40 48 S	88 51 E	−30.4	−28.3	−23.8	−29.1	− 2.1	− 6.6	− 1.3
13	40 33 S	88 58 E	−29.7	−27.8	−23.6	−28.8	− 1.9	− 6.1	− 0.9
14	39 02 S	89 49 E	−28.0	−26.2	−22.6	−27.1	− 1.8	− 5.4	− 0.9
14	37 45 S	90 53 E	−25.6	−24.5	−20.9	−25.3	− 1.1	− 4.7	− 0.3
14	37 34 S	91 02 E	−26.4	−23.7	−20.4	−25.0	− 2.7	− 6.0	− 1.4
15	35 58 S	92 32 E	−22.9	−21.4	−18.3	−22.7	− 1.5	− 4.6	− 0.2
15	35 41 S	93 33 E	−22.7	−20.6	−17.5	−21.7	− 2.1	− 5.2	− 1.0
15	35 32 S	93 56 E	−21.8	−20.2	−17.0	−21.3	− 1.6	− 4.8	− 0.5
16	34 55 S	95 20 E	−20.5	−18.9	−15.9	−19.8	− 1.6	− 4.6	− 0.7
16	34 09 S	96 23 E	−18.6	−17.8	−14.9	−18.6	− 0.8	− 3.7	0.0
17	34 54 S	95 36 E	−20.6	−18.7	−15.8	−19.7	− 1.9	− 4.8	− 0.9
18	36 11 S	95 23 E	−21.9	−20.1	−17.3	−21.2	− 1.8	− 4.6	− 0.7
19	36 10 S	96 58 E	−21.0	−19.4	−16.7	−20.3	− 1.6	− 4.3	− 0.7
19	35 56 S	97 34 E	−20.1	−18.8	−15.9	−19.6	− 1.3	− 4.2	− 0.5
19	36 02 S	97 36 E	−19.7	−19.0	−16.1	−19.8	− 0.7	− 3.6	+ 0.1
20	37 12 S	97 28 E	−21.4	−20.3	−17.3	−21.1	− 1.1	− 4.1	− 0.3
20	38 02 S	97 34 E	−22.2	−21.1	−18.2	−22.0	− 1.1	− 4.0	− 0.2
21	39 22 S	98 28 E	−23.0	−21.9	−19.1	−22.9	− 1.1	− 3.9	− 0.1
21	40 04 S	99 35 E	−23.7	−22.0	−19.3	−23.0	− 1.7	− 4.4	− 0.7
22	41 48 S	100 18 E	−25.6	−24.2	−20.5	−24.5	− 1.4	− 5.1	− 1.1
22	43 07 S	100 36 E	−26.2	−25.9	−21.9	−25.8	− 0.3	− 4.3	− 0.4
23	46 48 S	101 43 E	−31.8	−30.4	−25.5	−30.1	− 1.4	− 6.3	− 1.7
24	47 39 S	101 58 E	−32.6	−31.2	−26.5	−31.1	− 1.4	− 6.1	− 1.5
24	47 58 S	102 04 E	−33.4	−31.4	−26.6	−31.5	− 2.0	− 6.8	− 1.9
25	47 55 S	102 56 E	−33.0	−30.6	−26.1	−30.6	− 2.4	− 6.9	− 2.4
25	47 51 S	104 08 E	−30.3	−29.7	−25.1	−29.9	− 0.6	− 5.2	− 0.4
26	49 13 S	104 25 E	−33.7	−31.2	−26.6	−31.2	− 2.5	− 7.1	− 2.5
26	50 35 S	105 19 E	−34.4	−32.2	−27.7	−32.3	− 2.2	− 6.7	− 2.1
27	52 04 S	106 16 E	−36.5	−33.3	−28.9	−33.5	− 3.2	− 7.6	− 3.0
27	53 03 S	107 02 E	−37.4	−34.0	−29.4	−33.9	− 3.4	− 8.0	− 3.5
28	54 13 S	107 29 E	−40.4	−35.1	−30.3	−35.1	− 5.3	−10.1	− 5.3
29	57 10 S	108 17 E	−45.9	−37.7	−33.4	−37.5	− 8.2	−12.5	− 8.4
29	57 31 S	108 44 E	−45.4	−37.9	−33.4	−37.5	− 7.5	−12.0	− 7.9
Mar. 1	58 49 S	109 20 E	−49.6	−39.0	−34.9	−38.7	−10.6	−14.7	−10.9
1	58 59 S	109 36 E	−49.7	−39.1	−35.0	−38.8	−10.6	−14.7	−10.9
1	59 24 S	110 24 E	−50.6	−39.0	−34.6	−38.5	−11.6	−16.0	−12.1
1	59 17 S	110 51 E	−50.5	−38.5	−34.2	−38.0	−12.0	−16.3	−12.5
2	57 46 S	111 59 E	−44.5	−35.7	−31.4	−35.5	− 8.8	−13.1	− 9.0
2	56 18 S	112 33 E	−41.8	−33.2	−29.0	−33.0	− 8.6	−12.8	− 8.8
3	54 32 S	113 24 E	−36.2	−30.0	−25.8	−29.7	− 6.2	−10.4	− 6.5
3	53 25 S	113 51 E	−32.0	−28.2	−24.3	−28.0	− 3.8	− 7.7	− 4.0
3	53 02 S	114 04 E	−31.2	−27.5	−23.4	−27.0	− 3.7	− 7.8	− 4.2
4	51 34 S	115 56 E	−25.9	−23.5	−20.0	−23.5	− 2.4	− 5.9	− 2.4
4	51 27 S	117 34 E	−23.2	−21.4	−18.5	−21.5	− 1.8	− 4.7	− 1.7

Date	Position		Carnegie	Chart Values			Chart Corrections		
	Latitude	Longitude		Brit.[2]	Ger.[3]	U. S.[4]	Brit.	Ger.	U. S.
1916	° ′	° ′	°	°	°	°	°	°	°
Mar. 5	49 43 S	119 50 E	−17.4	−16.9	−14.3	−16.6	− 0.5	− 3.1	− 0.8
5	48 36 S	120 53 E	−14.9	−14.3	−11.7	−13.8	− 0.6	− 3.2	− 1.1
6	46 46 S	122 28 E	−10.4	−10.2	− 8.4	− 9.6	− 0.2	− 2.0	− 0.8
7	45 11 S	124 56 E	− 6.1	− 5.2	− 5.0	− 5.1	− 0.9	− 1.1	− 1.0
8	45 00 S	125 53 E	− 5.7	− 4.4	− 3.9	− 4.4	− 1.3	− 1.8	− 1.3
8	44 58 S	126 09 E	− 5.0	− 4.0	− 3.6	− 4.1	− 1.0	− 1.4	− 0.9
9	44 44 S	126 23 E	− 4.9	− 3.7	− 3.3	− 3.8	− 1.2	− 1.6	− 1.1
9	43 44 S	126 40 E	− 4.0	− 3.0	− 2.6	− 3.0	− 1.0	− 1.4	− 1.0
10	42 05 S	127 36 E	− 2.3	− 1.4	− 1.1	− 1.5	− 0.9	− 1.2	− 0.8
10	41 32 S	128 03 E	− 0.8	− 0.8	− 0.5	− 0.8	0.0	− 0.3	0.0
11	40 26 S	128 59 E	− 0.5	+ 0.2	+ 0.2	+ 0.3	− 0.7	− 0.7	− 0.8
11	40 21 S	129 01 E	− 0.4	+ 0.3	+ 0.3	+ 0.4	− 0.7	− 0.7	− 0.8
11	39 39 S	129 28 E	+ 0.1	+ 0.6	+ 0.7	+ 0.7	− 0.5	− 0.6	− 0.6
11	39 29 S	129 45 E	+ 0.3	+ 0.8	+ 1.0	+ 0.8	− 0.5	− 0.7	− 0.5
12	39 57 S	129 57 E	+ 0.4	+ 0.8	+ 0.9	+ 0.7	− 0.4	− 0.5	− 0.3
12	40 49 S	130 06 E	+ 0.1	+ 0.7	+ 0.8	+ 0.7	− 0.6	− 0.7	− 0.6
12	41 01 S	130 08 E	+ 0.2	+ 0.7	+ 0.7	+ 0.6	− 0.5	− 0.5	− 0.4
13	42 27 S	130 51 E	+ 0.2	+ 0.7	+ 0.6	+ 0.9	− 0.5	− 0.4	− 0.7
13	43 50 S	130 55 E	− 0.2	+ 0.3	+ 0.5	+ 0.4	− 0.5	− 0.7	− 0.6
14	45 41 S	130 50 E	− 0.7	− 0.5	0.0	− 0.1	− 0.2	− 0.7	− 0.6
14	47 08 S	130 51 E	− 1.2	− 1.0	− 0.9	− 1.0	− 0.2	− 0.3	− 0.2
15	48 24 S	132 19 E	− 1.2	− 0.2	− 0.1	0.0	− 1.0	− 1.1	− 1.2
15	49 09 S	132 50 E	− 1.2	− 0.1	0.0	0.0	− 1.1	− 1.2	− 1.2
16	50 20 S	132 56 E	− 1.8	− 0.7	− 0.5	− 0.5	− 1.1	− 1.3	− 1.3
16	51 00 S	132 42 E	− 1.4	− 1.2	− 1.4	− 1.1	− 0.2	0.0	− 0.3
17	53 13 S	132 02 E	− 5.3	− 3.7	− 4.0	− 3.8	− 1.6	− 1.3	− 1.5
17	54 27 S	132 07 E	− 6.7	− 4.8	− 5.1	− 4.9	− 1.9	− 1.6	− 1.8
17	54 37 S	132 08 E	− 6.1	− 5.0	− 5.4	− 5.0	− 1.1	− 0.7	− 1.1
18	56 36 S	132 54 E	− 8.9	− 6.0	− 6.2	− 6.0	− 2.9	− 2.7	− 2.9
18	56 37 S	133 27 E	− 8.2	− 5.2	− 5.8	− 5.2	− 3.0	− 2.4	− 3.0
19	56 40 S	134 26 E	− 7.9	− 3.8	− 4.8	− 3.7	− 4.1	− 3.1	− 4.2
19	57 13 S	135 50 E	− 4.6	− 2.4	− 3.3	− 2.0	− 2.2	− 1.3	− 2.6
19	57 25 S	135 53 E	− 5.3	− 2.5	− 3.4	− 2.2	− 2.8	− 1.9	− 3.1
20	57 08 S	137 54 E	− 2.9	+ 0.9	0.0	+ 1.0	− 3.8	− 2.9	− 3.9
20	57 12 S	139 10 E	+ 0.2	+ 2.5	+ 1.5	+ 2.6	− 2.3	− 1.3	− 2.4
21	56 57 S	142 07 E	+ 4.4	+ 6.7	+ 5.2	+ 6.4	− 2.3	− 0.8	− 2.0
22	56 52 S	144 33 E	+ 6.8	+ 9.8	+ 7.6	+10.0	− 3.0	− 0.8	− 3.2
23	56 41 S	146 57 E	+11.8	+11.8	+10.1	+11.6	0.0	+ 1.7	+ 0.2
24	54 35 S	150 40 E	+14.3	+13.7	+12.7	+13.7	+ 0.6	+ 1.6	+ 0.6
24	54 09 S	151 32 E	+13.8	+14.1	+13.2	+14.0	− 0.3	+ 0.6	− 0.2
25	53 07 S	153 50 E	+15.8	+15.2	+14.3	+15.0	+ 0.6	+ 1.5	+ 0.8
26	52 41 S	156 22 E	+16.0	+16.6	+16.1	+16.5	− 0.6	− 0.1	− 0.5
27	51 26 S	159 54 E	+17.6	+18.3	+17.3	+18.2	− 0.7	+ 0.3	− 0.6
27	50 30 S	161 34 E	+17.7	+18.9	+17.7	+18.7	− 1.2	0.0	− 1.0
28	48 49 S	163 29 E	+17.4	+18.7	+17.7	+18.5	− 1.3	− 0.3	− 1.1
28	48 27 S	164 44 E	+17.5	+18.6	+18.1	+18.7	− 1.1	− 0.6	− 1.2
29	48 12 S	167 08 E	+17.8	+18.9	+18.7	+19.2	− 1.1	− 0.9	− 1.4
29	47 13 S	169 15 E	+18.0	+18.4	+18.8	+18.8	− 0.4	− 0.8	− 0.8
30	46 39 S	170 32 E	+18.3	+18.3	+18.9	+18.6	0.0	− 0.6	− 0.3
30	45 50 S	171 22 E	+17.8	+18.2	+18.7	+18.3	− 0.4	− 0.9	− 0.5
31	44 59 S	172 31 E	+17.6	+17.9	+18.6	+18.0	− 0.3	− 1.0	− 0.4
31	44 31 S	173 04 E	+17.4	+17.7	+18.3	+17.7	− 0.3	− 0.9	− 0.3
Apr. 1	43 38 S	173 02 E	+17.2	+17.0	+17.8	+17.2	+ 0.2	− 0.6	0.0

Date	Position		Carnegie	Chart Values			Chart Corrections		
	Latitude	Longitude		Brit.[2]	Ger.[3]	U. S.[4]	Brit.	Ger.	U. S.
1916	° ′	° ′	°	°	°	°	°	°	°
May 10	43 32 S	172 48 E	+17.0	+17.1	+17.8	+17.2	− 0.1	− 0.8	− 0.2
17	43 33 S	172 56 E	+16.3	+17.1	+17.8	+17.2	− 0.8	− 1.5	− 0.9
18	43 41 S	174 07 E	+17.2	+17.1	+18.0	+17.3	+ 0.1	− 0.8	− 0.1
18	43 57 S	174 43 E	+17.2	+17.4	+18.2	+17.5	− 0.2	− 1.0	− 0.3
19	43 07 S	174 19 E	+17.1	+17.0	+17.8	+17.0	+ 0.1	− 0.7	+ 0.1
20	43 36 S	175 40 E	+17.2	+17.3	+17.9	+17.4	− 0.1	− 0.7	− 0.2
21	43 59 S	176 34 E	+17.6	+17.7	+18.3	+17.7	− 0.1	− 0.7	− 0.1
22	43 55 S	177 40 E	+17.6	+17.7	+18.2	+17.7	− 0.1	− 0.6	− 0.1
22	44 14 S	179 08 E	+17.6	+17.8	+18.3	+17.8	− 0.2	− 0.7	− 0.2
22	43 57 S	178 36 W	+17.9	+17.5	+17.9	+17.5	+ 0.4	0.0	+ 0.4
22	43 16 S	177 42 W	+17.4	+17.1	+17.5	+17.1	+ 0.3	− 0.1	+ 0.3
23	41 47 S	175 55 W	+16.7	+16.3	+16.7	+16.4	+ 0.4	0.0	+ 0.3
23	40 50 S	175 24 W	+16.6	+16.1	+16.3	+16.1	+ 0.5	+ 0.3	+ 0.5
24	39 57 S	174 21 W	+16.7	+15.5	+15.9	+15.7	+ 1.2	+ 0.8	+ 1.0
24	39 42 S	174 13 W	+16.2	+15.5	+15.7	+15.7	+ 0.7	+ 0.5	+ 0.5
25	37 26 S	173 35 W	+15.7	+14.9	+14.9	+14.9	+ 0.8	+ 0.8	+ 0.8
25	37 13 S	173 32 W	+15.4	+14.9	+14.8	+14.9	+ 0.5	+ 0.6	+ 0.5
25	35 59 S	172 59 W	+15.2	+14.7	+14.4	+14.7	+ 0.5	+ 0.8	+ 0.5
26	34 06 S	172 42 W	+14.2	+14.3	+13.8	+14.3	− 0.1	+ 0.4	− 0.1
26	33 04 S	172 42 W	+14.2	+14.1	+13.5	+14.1	+ 0.1	+ 0.7	+ 0.1
27	31 14 S	173 49 W	+13.5	+13.7	+13.1	+13.6	− 0.2	+ 0.4	− 0.1
28	30 59 S	173 58 W	+13.6	+13.6	+13.0	+13.5	0.0	+ 0.6	+ 0.1
29	30 36 S	172 15 W	+13.2	+13.5	+12.9	+13.3	− 0.3	+ 0.3	− 0.1
31	28 56 S	171 12 W	+13.1	+13.2	+12.5	+12.8	− 0.1	+ 0.6	+ 0.3
31	28 41 S	170 06 W	+13.3	+13.3	+12.5	+12.8	0.0	+ 0.8	+ 0.5
June 1	27 19 S	168 30 W	+12.4	+12.7	+12.0	+12.5	− 0.3	+ 0.4	− 0.1
1	26 17 S	168 23 W	+12.2	+12.5	+11.8	+12.3	− 0.3	+ 0.4	− 0.1
2	24 57 S	168 19 W	+12.0	+12.1	+11.6	+11.9	− 0.1	+ 0.4	+ 0.1
2	24 24 S	168 26 W	+11.8	+12.0	+11.5	+11.8	− 0.2	+ 0.3	0.0
3	22 22 S	169 04 W	+11.5	+11.5	+11.1	+11.4	0.0	+ 0.4	+ 0.1
5	18 45 S	170 55 W	+10.7	+10.9	+10.5	+10.7	− 0.2	+ 0.2	0.0
5	18 23 S	170 55 W	+10.4	+10.8	+10.4	+10.6	− 0.4	0.0	− 0.2
6	16 04 S	170 28 W	+ 9.8	+10.4	+10.0	+10.3	− 0.6	− 0.2	− 0.5
7	14 37 S	170 27 W	+ 9.9	+10.1	+ 9.7	+10.0	− 0.2	+ 0.2	− 0.1

[1] Crossed 180th meridian, hence May 22 occurs twice.

Secular Change of the Magnetic Declination in the Indian Ocean (Southeastern Part).

From the intersections of the *Carnegie's* tracks of 1911 and 1916 in the Indian Ocean, approximately in latitude 36° south, longitude 96° east, it is possible to determine the annual changes[7] of the magnetic elements. In this region both the isogonics and the isoclinics are crowded closely together. Thus a change in geographic position of one mile, in a northeasterly or a southwesterly direction, corresponds to a change of about 0.°02 in the magnetic declination. The average annual change in the magnetic declination (1911 to 1916) is determined as follows: Five declination stations selected from the results of 1911[8] have practically the same mean geographic position as eleven stations from the 1916 results, given in the preceding tables. The groupings are shown in the following table:

No.	Year and decimal		Latitude	Longitude	Declination
			°	°	°
1	1911	.94	34.67 S	91.57 E	21.0W
2		.94	36.05	93.28	21.9
3		.94	36.23	97.30	19.7
4		.94	35.93	97.73	19.0
5		.95	35.63	98.57	17.7
I.—Mean.	1911	.94	35.70 S	95.69 E	19.86W
6	1916	.12	35.97	92.53	22.9
7		.12	35.68	93.55	22.7
8		.12	35.53	93.93	21.8
9		.13	34.92	95.33	20.5
10		.13	34.15	96.38	18.6
11		.13	34.90	95.60	20.6
12		.13	36.18	95.38	21.9
13		.13	36.17	96.97	21.0
14		.13	35.93	97.57	20.1
15		.13	36.03	97.60	19.7
16		.14	37.20	97.47	21.4
II.—Mean.	1916	.13	35.70 S	95.66 E	21.02W
II.—I.		4.19	....	....	1.16W
Ann. Change.	....		....	....	0.28W

Accordingly, the average annual change in declination, for the geographic position 35°.7 south latitude and 95°.7 east longitude and the period 1911-1916, is, apparently, 0°.28 or 17′ (west decli-

[7] *Terr. Mag.*, v. 21. p. 105, 1916.

[8] *Terr. Mag.*, v. 17, p. 141, 1912; the value for Dec. 11, 1911 should read 19°.7 instead of 20°.0.

nation increasing). For the region 35°.3 south latitude and 74°.8 east longitude it was previously found from a comparison[9] of the *Carnegie* observations of 1911 with those of the *Gauss* in 1903, that west magnetic declination during the period 1903 to 1911 had been increasing at the average annual rate of 13'.—L. A. B. and W. J. P.

[9] *Terr. Mag.*, v. 16, p. 136, Table III, 1911.

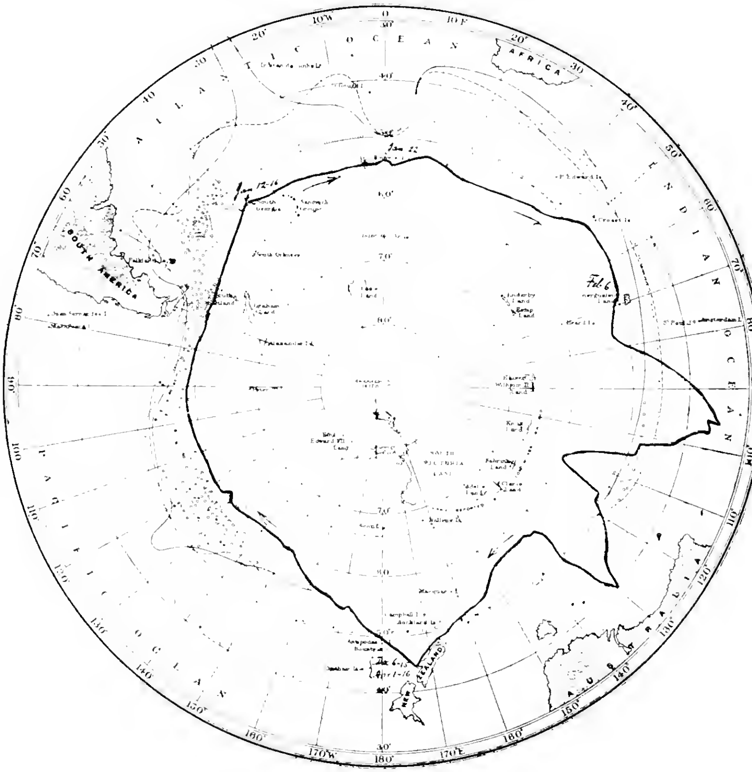


Fig. 1.—Track of the *Carnegie*, Dec. 6, 1915—Apr. 1, 1916. (Heavy Line.)

METEOROLOGISCHE UND LUFTELEKTRISCHE MESSUNGEN WÄHREND DER TOTALEN SONNENFINSTERNIS AM 10. OKTOBER 1912 AUF DER FACENDA BOÃ VISTA BEI CHRISTINA (PROV. MINAS GERAES-BRASILIEN). I.—METEOROLOGISCHE BEOBACHTUNGEN.

Von W. Knoche und J. Laub.

Vorwort.

Der Unterzeichnete erhielt kurz vor der Sonnenfinsternis vom 10. Oktober 1912 eine Einladung seitens des Direktors des Department of Terrestrial Magnetism der Carnegie Institution of Washington, Herrn Dr. L. A. Bauer, während der Finsternis in Brasilien vorzüglich luftelektrische Messungen auszuführen. Die Kosten der Expedition wurden zum Teil von der genannten Institution gedeckt. Der Expedition schloss sich Herr Dr. J. Laub, Professor an der Universität La Plata, an, durch deren Präsident, Senator Dr. J. V. Gonzalez, ihm dankenswerter Weise die Mittel hierzu zur Verfügung gestellt wurden.

Tiefgefühlten Dank zollen wir, durch besondere Anteilnahme seines Sekretärs, Herrn M. Vargas, dem Chilenischen Ministerium des Unterrichts, welches dem Unterzeichneten den nötigen Urlaub erteilte und ausserdem die Mitnahme des Mechanikers des Meteorologischen Instituts in Santiago, Herrn Waldemar Trollund, ermöglichte; der brasilianischen Regierung, insbesondere als ihrem Vertreter, dem Minister des Äusseren, Herrn Lauro Müller, für die generöse Gastfreiheit, die uns gewährt wurde; und Herrn H. Morize, dem Direktor des Observatorio Nacional in Rio de Janeiro, der in wahrhaft aufopfernder Weise alle Vorbereitungen getroffen hatte und uns nach unserer Ankunft in der brasilianischen Hauptstadt mit Rat und Tat unterstützte. Ferner sind wir zu grösstem Danke verbunden: Herrn Prof. Dr. P. v. Ihering, dem Direktor des Museu Paulista in São Paulo und seiner geschätzten Gattin; dem Oberlehrer an der Deutschen Schule in Rio de Janeiro, Herrn Dr. H. Schäfer; sowie Frau R. Laub, die im Interesse der Wissenschaft die recht beschwerliche Reise nach unserem Beobachtungsort Boã Vista nicht scheuten, um uns am Tage der Finsternis in unseren Arbeiten auf das wirksamste zu unterstützen.

W. Knoche.

EINLEITUNG.

Die Zone der totalen Sonnenfinsternis am 10. Oktober 1912 begann in $\phi = 3° 46' N, \lambda = 92° 31' W$, d. h. etwa nördlich der Galapagos Inseln im Stillen Ozean, und verlief dann, in die Republik Ecuador (in der Nähe der kolumbischen Grenze) eintretend, über Südkolumbien nach Brasilien (Amazonas, Matto Grosso, Goyaz, Minas Geraes, São Paulo), um bei Ilha Grande, südlich Rio de Janeiro, den südamerikanischen Kontinent zu verlassen, den Südatlantik zu durchqueren und etwa südwestlich von Possession Island im Indischen Ozean unter $\phi = 52° 7' S, \lambda = 46° 59' E$ zu enden. Für die Wahl des Ortes kamen folgende Gesichtspunkte in Betracht:

1) Die klimatischen Bedingungen sollten möglichst günstige sein. 2) Die Ortschaft sollte möglichst so gewählt werden, dass die Dauer der Totalität ein Maximum war, d. h. es musste in unserem Falle dafür gesorgt werden, dass der Ort möglichst in die Nähe der Küste zu liegen kam. Aus dem gleichen Grunde sollte er sich in der Zentralitätszone befinden. 3) Die Beobachtungsstation musste in Anbetracht des kostspieligen und empfindlichen Instrumentariums möglichst bequem zu erreichen sein und auch sonst allen billigen Anforderungen an Eignung entsprechen.

Die Facenda Boă Vista ($\phi = 45° 15' W, \lambda = 22° 14' S$; $H = 1011$ m) schien ein Optimum darzustellen. Die Küste selbst musste wegen ungünstiger klimatischer Bedingungen zurücktreten. Anderseits versprach ein zu weites Eindringen ins Innere keine günstigere Witterung, die Dauer der Totalität aber wurde verkürzt, und die Reisedauer verlängert. Boă Vista hingegen, nördlich der WNW-ESE streichenden Serra de Mantiqueira, in über 1000 m hohem offenen Bergland gelegen, schien bei gutem Wetter allen Bedingungen zu genügen; die Höhe erschien für unsere Untersuchungen besonders vorteilhaft. Ferner befand sich der Beobachtungsort in der Zentralitätszone, bot relativ grosse Bequemlichkeiten und war nur 4 bis 5 km von dem mit der Eisenbahn leicht erreichbaren Städtchen Christina (Minas Geraes) entfernt, das etwa 3000 Einwohner zählt.

Der Beginn der Sonnenfinsternis am 10. Oktober 1912 fiel in Boâ Vista auf $8^h 54^m 29^s$, ihr Ende auf $11^h 40^m 42^s$ M. Z. (am Beobachtungsort). Die Totalität, von 112 sec Dauer, begann um $10^h 13^m 30^s$ und endete um $10^h 15^m 22^s$ M. Z. In Boă Vista arbeitete ausser uns die chilenische Kommission (Astronomisches Observatorium Santiago) und in Christina eine argentinische (Astronomisches Observatorium Cordoba).

Knoche verliess am 5. September 1912 Santiago de Chile, um,

da die Kordillereneisenbahn im Betrieb durch Schneeverwehungen gehindert war, über Valparaiso-Magallanes Rio de Janeiro zu erreichen. Die Seefahrt wurde benutzt, um einige Bestimmungen der Radioaktivität der Luft auszuführen.[1] In Montevideo stiess Herr Dr. J. Laub und Gemahlin, von La Plata kommend, zu uns. Die Tage, die uns in Rio de Janeiro verblieben, wurden fleissig benutzt, um Erkundigungen einzuziehen, die letzten Vorbereitungen zu treffen, die Barometer zu vergleichen u. s. w. Herr Morize vor allen unterstützte uns hierbei durch seine Ratschläge und sein Entgegenkommen.

Am 25. September früh verliessen wir die brasilianische Hauptstadt, kreuzten im Zuge das waldgeschmückte Küstengebirge, durchfuhren dann das Tal des Parahyba bis Cruzeiro, wo die Hauptlinie Rio-São Paulo verlassen wird. Eine Schmalspurbahn führt von hier aus durch die hohe Serra de Mantiqueira. Die Änderung der Spurweite war auch die Ursache, dass das zahlreiche Gepäck umgeladen werden musste. Von Vorteil war es hierbei, dass wir zwar zahlreiche, dafür aber nicht sehr schwere Instrumentenkisten bei uns hatten, und dass uns dankenswerterweise besondere Gepäckwagen zur Verfügung standen. Beim Aufstieg ins Gebirge änderte sich bald die Vegetation, der Urwald schwand, gruppenweise traten brasilianische Pinien auf, auch Weideland; die Höhen selbst machten einen ziemlich öden Eindruck. Nach einem nochmaligen Wagenwechsel in Soledade erreichten wir nach 11stündiger Fahrt abends 6 Uhr Christina.

Nachdem am nächsten Tage die in der Nähe gelegene, dem Obersten Feraz gehörende Facenda Boã-Vista besichtigt war, wurden am 26. unsere Instrumente auf die landesüblichen, bootförmigen, schweren Ochsenwagen geladen, welche von je vier Jochen gezogen werden. Da der Weg nicht übermässig gut war, so gerieten wir einigermassen in Sorge um die Apparate und waren befriedigt, dass wir sie unbeschädigt den Kisten entnehmen konnten.[2]

[1] *Terr. Mag.*, 18. Bd., 1913, S. 71-74.

[2] Es sei hier einiges über die Verpackung von Instrumenten bemerkt, welche auf Reisen, wo ein häufiges Umladen von nöten, wo die Behandlung eine mitunter sehr rohe ist, von grösster Bedeutung erscheint. Beschädigte Elektroscope, zerbrochene Thermometer — besonders empfindlich sind Schwarzkugel- und Erdbodenthermometer — können peinlichste Überraschungen hervorrufen. Die Erfahrung hat uns gelehrt, dass bei der Verpackung weder an Gewicht noch an Geld gespart werden darf. Meteorologische und luftelektrische Instrumente, welcher Art sie auch seien, befinden sich zunächst in modellierten Kästchen oder Hülsen aus leichtem, aber festem Holz, so dass alle ihre Teile gestützt und immobilisiert sind. Mehrere solcher Instrumentenkästchen, möglichst zur gleichen Gruppe gehörig, werden in kräftig gearbeitete, mit Calico und Ölfarbenanstrich versehene Kisten, die einen gut abschliessenden Gummirand besitzen, verpackt, und zwar wiederum in vormodellierte Abteilungen. Dies sind die eigentlichen Instrumentenkästen, welche an Ort und Stelle leicht transportabel und handlich sind. Für den Ferntransport werden diese jede für sich, in grössere Holzkisten mit gepolsterten Ledérecken unter Beifügung von Holzwolle verpackt.

Wie oben bemerkt wurde, bot die Facenda die günstigsten Bedingungen; doch ist dies nur in relativem Sinne zu verstehen. Nach den für das Gebiet vorliegenden meteorologischen Beobachtungen hatten wir im Monat Oktober nur etwas in 50 Prozent der Tage heiteren Himmel zu erwarten, ein nicht übermässig vielversprechendes Resultat. Es wurde ja in der Tat am Tage der Finsternis all unsere Hoffnung auf ein günstiges Wetter vernichtet, wenn auch immerhin einigermassen befriedigende Resultate gewonnen wurden. Wäre der Himmel wolkenlos gewesen, so hätten wir trotzdem unter einer ev. für die luftelektrischen Beobachtungen verhängnisvollen Störung zu leiden gehabt, die wir vorher nicht in Rechnung gezogen hatten, die aber bei künftigen Expeditionen totaler Sonnenfinsternisse in gewissen Ländern zu beachten ist: die Erzeugung von Haarrauch infolge des Abbrennens der Felder und Wälder bei der Vorbereitung zur Ernte. Dem Rauch sind vielleicht die Störungen der luftelektrischen Beobachtungen an den Vortagen der Finsternis zu danken; am Tage der Totalität genossen wir allerdings den zweifelhaften Vorzug, durch den andauernden Regen die Brandtrübung beseitigt zu sehen.—W. K.

METEOROLOGISCHE BEOBACHTUNGEN.

VON W. KNOCHE.

Wenn in erster Linie auch luftelektrische Messungen in Frage kamen, so waren zu deren Diskussion möglichst ausführliche, meteorologische Beobachtungen, abgesehen von ihrem absoluten Werte, von nöten. Vorweggenommen sei, dass *lichtelektrische Messungen* mittelst Selenzellen am Tage der Finsternis wegen gestörter Isolation bei dem strömenden Regen ein völlig ungenügendes Resultat ergaben.

An *meteorologischen Apparaten* (Fabrikate Fuess-Berlin-Steglitz und Richard-Paris) standen die folgenden zur Verfügung:

1. Zur Registrierung des Luftdrucks ein Barograph (grosses Modell) mit täglichem Umlauf, zur direkten Ablesung ein Stationsbarometer und als Reserveinstrument ein Reise-Heberbarometer.

2. Zur Registrierung des Sonnenscheins ein Sonnenscheinautograph Campbell-Stokes.

3. Zur relativen Registrierung der Strahlung ein Viollesches Aktinometer (mit täglichem Umlauf), zur direkten Ablesung ein Schwarzkugelthermometer sowie je ein Schwarzkugel-Maximum- und Minimumthermometer.

4. Zur Registrierung der Temperatur drei Thermographen (grosses Modell, wöchentliche Umdrehung), zur direkten Ablesung verschiedene Thermometer und Extremthermometer.

5. Zur Registrierung der Feuchtigkeit drei Hygrographen (grosses Modell, wöchentlicher Umlauf), zur direkten Ablesung zwei grosse Assmannsche Aspirationspsychrometer sowie ein Augustsches Psychrometer.

6. Zur Niederschlagsmessung ein Hellmanscher Regenmesser.

7. Zur Registrierung der Verdunstung ein Evaporigraph nach Kassner (mit täglicher Umdrehung).

8. Zur Registrierung der Windrichtung eine mechanisch zeichnende Windfahne, zur Bestimmung der Windgeschwindigkeit ein kleines Taschenanemometer mit Schalenkreuz.

9. Zur Bestimmung des Wolkenzuges ein kleiner Wolkenspiegel.

Die Facenda Boã-Vista, inmitten eines bergigen Hochlandes in einem langgestreckten flachen Thal gelegen, bot für die Aufstellung der Instrumente höchst günstige Bedingungen. Das unbewohnte zweistöckige Gebäude enthielt mehr als genug Räumlichkeiten; ein riesiger ebener Hof, zwischen einem kleinen Fluss und einem Hügelzuge gelegen, erlaubte eine ungestörte Einrichtung der meteorologischen Station. Um das Vieh und vor allem die Schweine abzuhalten, wurde ihre Einzäunung mit einem Drahtgitter unbedingt nötig.

Mittlerer Zustand der Meteorologischen Elemente in Boã Vista.

Bevor auf die Verhältnisse am Finsternistage eingegangen sei, möge eine kurze Besprechung des *mittleren Zustandes der verschiedenen meteorologischen Elemente während unserer Arbeit an der Station*, *vom* 1.-12. *Oktober* 1912, stattfinden. (Tabellen 1, 2.)

Wir haben ziemlich bedeutende Schwankungen des Luftdrucks, innerhalb von 10 Tagen, ein höchstes Tagesmittel mit 682.8 mm., ein tiefstes mit 676.4 mm.; am 2. und 3. empfangen wir die letzten Niederschläge einer abziehenden Depression. Vom 9. ab bringt eine neue Depression starken Regenfall, der gerade am Finsternistage sein Maximum (11 . X . 7 a: 31.3 mm) erreicht. Auch die Temperatur zeigt beträchtliche Schwankungen; in der Sonne haben wir ein Maximum von fast 52° C, im Schatten von 23°.5 C, in der Hütte ein Minimum von 1°.2 C, im Freien von sogar $-0°.7$ C. Kein Wunder also, dass die Nächte empfindlich kalt erschienen, da wir uns gegen Kälte nicht vorgesehen hatten. Am Tage waren die Temperaturverhältnisse angenehme. Es scheint, dass die Mitteltemperatur, der Lage des Ortes nach, eine höhere sein müsste als die von uns gefundene von 13°.0 C (2.–11. Okt.); im Vergleich zu der benachbarten Station Caxambú ($\phi = 22° 11' S, \lambda = 45° 01' W, H = 890$ m), für die gleichzeitige Beobachtungen der Tempera-

Tabelle 1.—*Witterungsverhältnisse in Boâ Vista (Christina), Brasilien, 2.—11. Oktober, 1912.*

Datum 1912	Temperatur						Niederschlag				Bewölkung							Bemerkungen*
	Freien			Schatten							0 — 10				Art und Richtung			
	Max	Min	Schw	Max	Min	Schw	9p-7a	7a-2p	2p-9p	7a-7a	7 a	2 p	9 p	Mittel	7 a	2 p	9 p	
	° C	° C	° C	° C	° C	° C	mm	mm	mm	mm								
Okt. 2	21.6	6.3	15.3	17.7	7.5	10.2	....	0.5	7.1	....	$10^1 t$	10^1	10	10.0	ni, str	ni, fr-ni, str, fr-str	ni(?)	r^1 (10^h 25^m-30^ma), r^0 ($10^h 30^m$ 35^ma), rr^0 (2^h 05^m-20^mp) rr^1 (2^h 20^m—3^h 38^mp), r öfters seit 3^h 38^mp, r^2 (8p—n), t (fr), b^1 Fetzen p, d^0 (fr Gebirge)
3	50.0	3.5	46.5	22.5	6.8	15.7	12.7	....	....	20.3	10^1	8^2	0	6.0	ni, fr-ni, str	cu, fr-cu, cu-ni	....	r^1 (n)
4	49.1	4.5	44.6	23.1	6.8	16.3	....	....	....	....	$8^1 st$	$3^1 s$	0	3.7	str-cu WNW	cu-ni NW	....	t^1 (n), t^0 (abd.), Rauch ^{0} (Brennen beginnt)
5	51.8	4.5	47.3	18.6	9.3	9.3	....	....	....	....	9^1	9^1	1^1	6.3	str-cu NW, ni	cu-ni N, ni	(?)	Rauch^1 (p) (Brennen)
6	49.1	1.4	47.7	19.7	3.6	16.1	....	....	....	....	$10^1 t$	8^2	0	6.0	ni NNW, str NNW	cu-ni NNW, str-cu NNW	....	t (n-fr, abd.), Rauch ^{0} (Gebirge
7	48.9	-0.7	49.6	23.3	1.2	22.1	....	....	....	....	$3^0 t$	$0s$	0	1.0	ci-str NNW	....	....	t^2 (n-fr), Rauch ^{1} (Brennen an einigen Orten)
8	50.1	0.5	49.6	23.5	2.1	21.4	....	....	....	....	$6^0 t$	8^1	0	4.7	ci-str E	fr-cu, cu-ni, str-cu, str	....	t^0 (n-fr, abd.), d^0 u. Rauch ^{1} (p Gebirge)
9	40.1	6.6	33.5	16.9	9.2	7.7	....	4.0	0.8	....	8^1	$10^1 r$	$10^1 r$	9.3	cu, str-cu, a-cu, ci	ni, fr-str	ni, fr-ni	r^1 (ohne Unterbrechung 11 15^ma-8^hp), r^0 (8p-n), b^1 (Gebirge), Rauch (fr; Gebirge)
10	16.3	13.5	2.8	14.2	12.3	1.9	6.8	13.0	11.2	11.6	$10^1 r$	$10^1 r$	$10^1 r$	10.0	ni, str	ni, str	ni (?)	r^1 (Mttn.-7^h 15^ma), r^0 (7^h 15^m 30^ma), r^1 (7^h 30^ma-n), b während d. ganzen Tages
11	26.0	10.5	15.5	16.8	10.6	6.2	7.1	10.4	3.0	31.3	$10^1 r$	$5^1 r$	2^1	5.7	ni, str	cu	cu (?)	r^1 (n-0^h 30^mp; 2p-5p)

* Es bedeuten: s = Sonne, t = Tau; r = Regen, rr = Rieselregen, b = Bergnebel, d = Dunst; fr = früh, n = nachts; Exponente: ^{0} = schwach, ^{1} = mittel, ^{2} = stark.

tur vorliegen, ergibt sich die ausserordentlich hohe Temperaturabnahme von 1°.4 C pro 100 m (Mittel 5.—10. Okt.). Die relative Feuchtigkeit in Boã Vista ist im Mittel 80 Prozent (2.—11. Okt.).

Bedingt durch die Tallage der Station sind vielleicht die Windverhältnisse; die fast andauernde Windstille deutet darauf hin. In dieser Hinsicht (zur Beobachtung ev. Finsterniswindes) dürfte eine Station in weniger geschützter Lage vorzuziehen sein. Die Bewölkungsverhältnisse sind im ganzen nicht sehr günstige; morgens ist die höchste Bewölkungszahl zu verzeichnen (nur ein Tag weniger als halb bewölkt) während abends mit Ausnahme der Regentage ein völliges Aufklären eintritt. Es scheint hier fast ein typisches Verhalten vorzuliegen. Auf jeden Fall liegt unsererseits sowohl wie auch seitens der anderen Expeditionen das schwere Versäumnis vor, keine genügende Erkundung nach dem täglichen Gang der Bewölkung eingezogen zu haben. Die mittlere Bewölkungszahl besagt hier (und an vielen anderen Örtlichkeiten, z. B. auch in Nordchile und Peru) gar nichts, wenn ein ausgeprägter täglicher Gang vorhanden ist.

TABELLE 2.—*Tages-Wert (24 Stunden-Mittel) der Meteorologischen Elemente in Boã Vista (Christina), Brasilien, 2.—11. Oktober,* 1912.

Datum 1912	Tages-Mittel.											Wind		Tages-Summe	
	1. Luftdruck 600 mm +	2. Strahlungs-temperatur.	3. Temperatur i. d. Hütte.	4. Temperatur ü. d. Boden.	5. Temp., 10 cm Bodentiefe.	6. Rel. Feuch't, i. d. Hütte.	7. Rel. Feuch't ü. d. Boden.	8. Rel. Feuch't, 10 cm Bodentiefe.	9. Abs. Feuch't, i. d. Hütte.	10. Abs. Feuch't, ü. d. Boden.	11. Abs. Feuch't, 10 cm Bodentiefe.	12. Richtung	13. Stärke (B.)	14. Dauer des Sonnenscheins.	15. Verdunstung.
	mm	° C	° C	° C	° C	%	%	%	mm	mm	mm			h	mm
Okt. 1	....	....	....	....	....	....	....	....	....	....	....	....	....	2.2	....
2	76.4	14.9	13.9	....	....	93	....	....	11.3	....	....	....	....	0.0	0.4
3	77.4	24.4	15.9	14.7	....	71	82	....	9.6	10.4	....	C	0	6.2	3.3
4	80.0	22.7	13.7	13.6	....	69	73	....	7.6	8.1	....	C	0	9.3	3.3
5	81.9	17.5	12.9	12.4	....	71	76	....	7.8	8.2	....	C	0	3.9	2.5
6	82.8	14.6	10.7	11.0	....	75	73	....	7.1	6.9	....	C	0	5.4	2.7
7	81.9	20.2	11.0	10.7	....	68	75	....	6.0	6.8	....	C	0	10.6	2.8
8	80.6	20.0	12.3	11.5	15.7	74	84	80	7.6	8.5	10.4	C	0	6.8	2.6
9	80.7	16.1	13.2	12.7	15.2	92	95	97	10.3	10.4	12.5	C	0	0.0	0.6
10	78.5	14.6	12.9	13.0	14.8	97	100	100	10.8	11.2	12.6	C	0	0.0	0.1
11	77.3	17.4	13.0	13.6	14.7	94	100	100	10.5	11.6	12.5	C	0	0.2	0.2
Mittel	79.7	18.2	13.0	12.6	15.1	80	84	94	8.9	9.1	12.0	C	0	4.0	1.8

Täglicher Gang der Meteorologischen Elemente in Boã Vista.

Betrachten wir kurz den *täglichen Gang der verschiedenen meteorologischen Elemente* (Tabelle 3, Fig. 1).

Luftdruck.—Der Barograph und die Barometer, mit denen er um 7a, 2p und 9p täglich verglichen wurde, befand sich in einem Zimmer im Erdgeschoss des Wohngebäudes. Tabelle 3 (Kol. 1 u. 2.) enthält die Stundenwerte vom 10. Oktober, sowie die Mittel vom 2.—11. Oktober. Der tägliche Gang tritt trotz der geringen Zahl der Beobachtungen gut hervor; irgend eine Störung ist an keinem Tage zu bemerken, auch nicht beim Vorübergang der Depressionen. Die folgenden Abweichungen in mm vom Tagesmittel (679.7 mm) zeigen an, dass der Verlauf dem für unsere Station zu erwartenden ausgeprägt doppeltperiodigen entspricht:

1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	Mittag
0.0	−0.4	**−0.6**	−0.5	−0.3	+0.1	+0.5	+0.9	*+1.1*	+1.0	+0.8	+0.4
13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h	Mttn.
0.0	−0.6	−0.8	**−1.0**	−0.9	−0.6	−0.3	+0.1	+0.5	*+0.6*	+0.6	+0.4

Es findet sich ein erstes Hauptmaximum zwischen 9a und 10a, ein zweites sekundäres zwischen 10p und 11p, ein erstes sekundäres Minimum zwischen 3-4a, und ein zweites Hauptminimum um 4p. Wir haben also eine Tagesschwankung von 2.1 mm und eine nächtliche von 1.6 mm. Als tägliche Amplitude erhalten wir 1.85 mm. Dies wäre der Breite entsprechend ein etwas zu hoher Wert, der aber durch die Tallage von Boã Vista erklärt wird.

Sonnenschein.—Der Sonnenscheinautograph war auf einem Holzpfeiler in 2 m Höhe über dem Boden im Hofe aufgestellt und konnte während des ganzen Tages von den Sonnenstrahlen getroffen werden. In 11 Tagen, v. 1.—11. Oktober, haben wir nur 44.6 Stunden Sonnenschein; am 2., 9. und 10. kommt die Sonne überhaupt nicht zum Vorschein. Für den täglichen Gang siehe Kolumne 23 der Tabelle 3 und Figur 1.

Zur Zeit der 7a-Beobachtung herrscht meist eine hohe Bewölkung; die Bewölkung nimmt ersichtlich von da an sehr schnell ab, da der Heliographenwert 7a—8a sofort ein sehr hoher ist; von 8a—9a haben wir das Maximum (6.3) des täglichen Sonnenscheins. Die geringe Anzahl der Tage erlaubt natürlich keine Feststellung, ob das Minimum des Sonnenscheins um die Mittagsstunden ein reelles ist. Es findet sich aber ein entsprechendes Minimum auch in dem Mittel der Strahlungstemperaturen ausgeprägt.

Temperatur im Freien.—Der Aktinograph wurde nur zur relativen Messung benutzt, gewissermassen als registrierender Schwarz-

kugelthermograph. Hierzu wurde die Kurve, welche der geschwärzten Kugel entsprach — die der blankpolierten wurde nicht in Betracht gezogen—um 7a, 2p und 9p mit den Ablesungen eines Schwarzkugelthermometers sowie ausserdem eines Schwarzkugelextremthermometers korrigiert, d. h. es wurde wie bei der Bearbeitung eines Thermographen vorgegangen. Die Stundenwerte der Tabelle 3 (Kol. 4) zeigen einen abgeschwächten Gang der Strahlungstemperaturen, da die vorhandenen trüben Tage (die Hälfte aller Tage) die Amplitude stark herabdrücken.

Als Mittel der Tage vom 2.—11. Oktober erhalten wir bei einem Minimum von 8°.0 C und einem Maximum von 30°.6 C eine Schwankung von 22°.6, während der 7. Oktober (Max. 48°.9 und Min. —0°.7) mit einer Amplitude von 49°.6 einem heiteren Tage zur Zeit unseres Aufenthaltes in Boâ Vista entsprechen würde. Das Minimum der Temperatur im Freien liegt nur 0°.5 unter dem der Temperatur in der Hütte, die Schwarzkugelhöchsttemperatur aber um 11°.6 C. über dem Schattenmaximum. Interessant ist im täglichen Gang der Strahlung ein doppeltes Maximum, das aber auch andernorts recht häufig ist. Die Temperatur, welche um 3a. im Mittel ihren tiefsten Stand, dessen Eintreten an den verschiedenen Tagen stark variiert, erreicht, steigt in den ersten Morgenstunden von 6a—9a, wie zu erwarten, stark an, um zwischen 8a—11a, also am Vormittag, ein erstes Maximum zu erreichen; dann setzt eine Depression und damit wiederum ein Anstieg in den Nachmittagsstunden ein. Das in den Mittelwerten auftretende, doppelte Maximum scheint ein reelles zu sein, da es an keinem Tage fehlt, selbst nicht an den trüben; wir finden es auch im Gange der Sonnenscheindauer angedeutet. Die kurze Reihe der Beobachtungen erlaubt es leider nicht, Schlüsse aus dieser interessanten Erscheinung zu ziehen (s. Hann, Lehrb. d. Meteorol., S. 35-36).

Temperatur im Schatten und am Boden.—Es war bei den Temperaturbeobachtungen geplant, am Sonnenfinsternistage auch Untersuchungen über die ev. Verschiebung der Eintrittszeit einer auftretenden Abkühlung in einer geringen Bodentiefe, am Boden und in der Hütte anzustellen. Leider war die Witterung am Finsternistage gerade dieser Vornahme sehr hinderlich, da das Sinken der Temperatur sehr gering war. Immerhin wurden die drei Thermographen in folgender Weise aufgestellt; einer in der Englischen Hütte in 2 m Höhe über dem Boden, einer auf dem Boden (Thermokörper 5 cm darüber) und ein weiterer in einem Loche, das in den lehmigen Boden gegraben wurde, so dass sich der Thermo-

TABELLE 3.—*Stündliche Werte der meteorologischen Elemente nach den Beobachtungen in Boã Vista, Brasilien, am Finsternistage und im Mittel.*

Mittlere Ortszeit.	1. Luftdruck 10. Oktober.	2. Luftdruck Mittel, 2.-11. Oktober.	3. Strahlungstemp. 10. Oktober.	4. Strahlungstemp. Mittel, 2.-11. Okt.	5. Temp. i. d. Hütte 10. Oktober.	6. Temp. i. d. Hütte Mittel, 2.-11. Okt.	7. Temp. ü. d. Boden 10. Oktober.	8. Temp. ü. d. Boden Mittel, 3.-11. Okt.	9. Tem., 10 cm Bodentiefe, 10. Oktober.	10. Tem., 10 cm Bodentiefe, 8.-11. Okt.	11. Rel. Feuch't i. d. Hütte, 10. Okt.	12. Rel. Feuch't i. d. Hütte, 2.-11. Okt.	13. Rel. Feuch't ü. d. Boden, 10. Okt.	14. Rel. Feuch't ü. d. Boden, 3.-11. Okt.	15. Rel. Feuch't, 10 cm Tiefe, 10. Okt.	16. Rel. Feuch't, 10 cm Tiefe, 8.-11. Okt.	17. Abs. Feuch't i. d. Hütte, 10. Okt.	18. Abs. Feuch't i. d. Hütte, 2.-11. Okt.	19. Abs. Feuch't ü. d. Boden, 10. Okt.	20. Abs. Feuch't ü. d. Boden, 3.-11. Okt.	21. Abs. Feuch't, 10 cm Tiefe, 10. Okt.	22. Abs. Feuch't, 10 cm Tiefe, 8.-11. Okt.	23. Sonnenscheindauer*, 1.-11. Oktober.	24. Verdunstung*, Stünd. S., 2.-11. Okt.	Wind. 10. Okt. 25. Richtung.	Wind. 10. Okt. 26. Starke. (B)	Wind. 4.-11. O. 27. Mitt. Richtung.	Wind. 4.-11. O. 28. Mitt. Starke.
h	mm	mm	°C	°C	°C	°C	°C	°C	°C	°C	%	%	%	%	%	%	mm	mm	mm	mm	mm	mm		mm				
1	679.5	679.7	14.0	8.7	12.5	8.8	12.5	9.2	14.9	13.8	97	92	100	95	100	98	10.5	8.0	10.8	8.5	12.6	11.6	....	0.1	C	0	C	0
2	79.1	79.3	13.7	8.3	12.5	8.5	12.5	8.8	14.9	13.6	97	93	100	95	100	98	10.5	8.0	10.8	8.2	12.7	11.5	....	0.0	C	0	C	0
3	78.6	79.1	13.7	8.0	12.5	8.5	12.4	8.5	14.9	13.6	97	91	100	95	100	99	10.5	7.8	10.8	8.2	12.7	11.5	....	0.0	C	0	C	0
4	78.3	79.2	13.7	8.2	12.5	8.6	12.4	8.4	14.9	13.4	98	92	100	95	100	99	10.6	7.9	10.8	8.2	12.7	11.4	....	0.1	C	0	C	0
5	78.2	79.4	13.6	8.4	12.4	8.5	12.4	8.4	14.9	13.2	98	92	100	96	100	99	10.6	7.9	10.8	8.2	12.7	11.3	....	0.1	C	0	C	0
6	78.7	79.8	13.5	8.5	12.5	8.7	12.5	8.4	14.9	13.2	98	91	100	96	100	99	10.6	7.9	10.8	8.2	12.7	11.3	....	0.1	C	0	C	0
7	79.3	80.2	13.8	16.7	12.8	10.2	12.8	10.7	14.9	13.9	98	89	100	95	100	99	10.8	8.4	11.0	9.2	12.7	11.8	0.7	0.0	C	0	C	0
8	79.6	80.6	15.7	23.4	13.2	12.3	13.1	12.6	15.1	14.4	97	80	99	83	100	95	11.0	8.7	11.0	9.1	12.8	11.7	6.1	0.3	C	0	C	0
9	79.7	80.8	15.2	28.9	13.3	14.4	13.4	15.0	15.2	15.1	97	73	100	74	100	88	11.0	8.9	11.5	9.5	12.9	11.2	6.3	0.9	C	0	C	0
10	79.4	80.7	14.2	29.3	13.4	15.8	12.8	15.9	15.1	15.7	96	70	100	71	100	88	11.0	9.3	11.0	9.5	12.8	11.7	4.6	1.1	W	1	C	0
11	79.2	80.5	14.1	29.8	13.3	16.5	13.0	16.6	14.9	16.1	97	69	100	71	100	86	11.0	9.5	11.2	9.8	12.7	11.5	4.6	1.5	W	1	C	0
Mitt'g	78.8	80.1	15.9	30.6	13.2	17.0	13.5	16.8	15.2	16.6	96	67	100	71	100	84	10.8	9.4	11.6	9.9	12.9	11.6	3.5	1.4	W	1	C	0
13	78.6	79.7	15.5	28.9	14.2	17.2	13.4	16.7	15.2	16.6	96	68	98	70	100	88	11.6	9.6	11.2	9.6	12.9	12.0	3.8	1.5	W	1	C	0
14	78.0	79.1	15.6	30.5	13.7	18.1	13.5	17.2	15.2	16.6	97	66	99	69	100	88	11.3	9.8	11.4	9.8	12.9	12.1	3.6	1.7	C	0	C	0
15	77.7	78.9	15.9	30.6	13.4	19.0	13.6	17.2	15.2	16.6	97	65	99	69	100	89	11.1	10.1	11.5	9.7	12.9	12.3	5.5	1.9	C	0	C	0
16	77.5	78.7	15.9	29.8	13.4	17.9	13.4	16.9	14.9	16.4	98	66	100	69	100	90	11.2	9.5	11.5	9.6	12.7	12.4	4.1	1.9	C	0	C	0
17	77.5	78.8	15.8	23.1	13.5	16.9	13.3	15.6	14.8	16.3	98	69	101	76	100	92	11.3	9.6	11.4	9.9	12.6	12.4	1.3	1.5	C	0	C	0
18	77.8	79.1	14.8	16.5	13.1	15.0	13.3	13.7	14.8	16.0	97	74	101	83	100	94	10.9	9.3	11.4	9.7	12.6	12.5	0.5	1.0	C	0	C	0
19	77.9	79.4	14.6	14.8	12.7	13.8	13.3	12.8	14.6	15.9	97	80	100	87	100	96	10.6	9.5	11.4	9.6	12.4	12.8	....	1.1	C	0	C	0
20	78.1	79.8	14.3	13.2	12.6	12.7	13.2	11.6	14.6	15.7	96	84	100	90	100	98	10.4	9.3	11.3	9.3	12.4	13.0	....	0.7	C	0	C	0
21	78.4	80.2	14.0	11.7	12.5	11.6	13.1	11.0	14.4	15.4	96	86	100	91	100	99	10.4	8.9	11.3	8.9	12.3	12.9	...	0.5	C	0	C	0
22	78.1	80.3	14.2	10.5	12.5	10.9	13.0	10.6	14.2	15.0	95	88	100	92	100	99	10.3	8.8	11.2	8.8	12.1	12.6	....	0.3	C	0	C	0
23	77.9	80.3	14.3	10.0	12.5	10.2	13.0	9.6	14.1	14.7	94	90	100	93	100	99	10.2	8.5	11.2	8.5	12.0	12.3	...	0.5	C	0	C	0
Mitt't	77.7	80.1	14.0	9.7	12.5	9.6	13.0	9.5	14.1	14.6	95	90	100	94	100	99	10.3	8.2	11.2	8.6	12.0	12.3	...	0.3	C	0	C	0
Mittel	678.5	679.7	14.6	18.2	12.9	13.0	13.0	12.6	14.8	15.1	97	80	100	84	100	94	10.8	8.9	11.2	9.1	12.6	12.0	....	....	C	0	C	0

* Verdunstung in mm pro Stunde; so ist z. B. die Summe, 12-1a., Okt. 2.-11. (10 Tage), gleich 0.1. Am 10. Okt. war die Verdunstung fast für jede Stunde 0.0, bloss für 2-3p war sie 0.1.

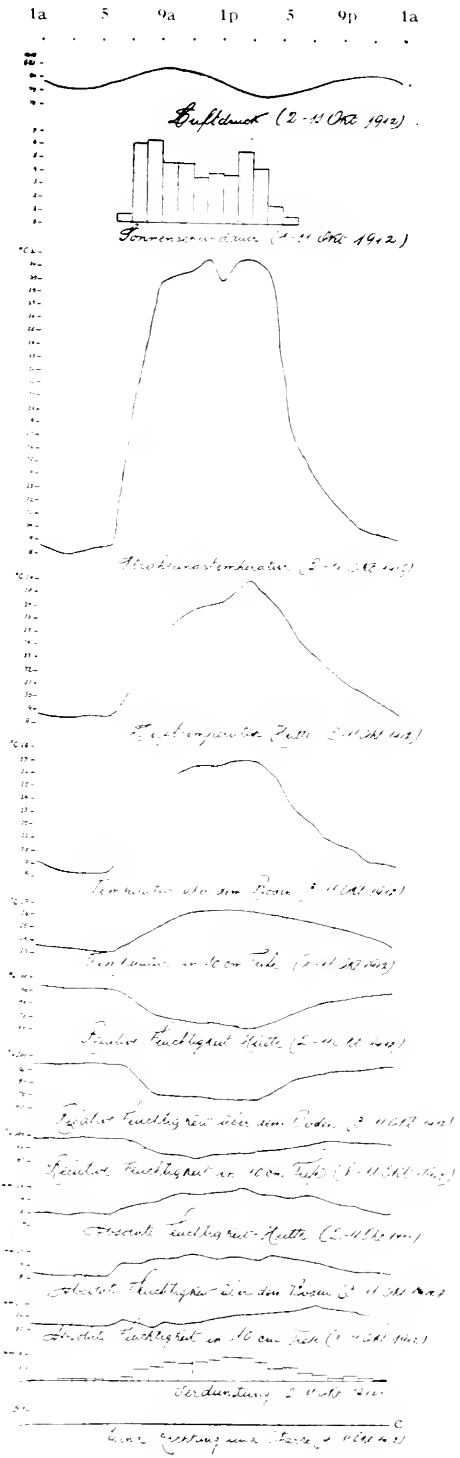


FIG. 1.—Tageskurve der Meteorologischen Elemente in Boá Vista (Christina), Brasilien, im Oktober 1912 (s. Tabelle 3).

körper in 10 cm Tiefe befand. Es ist zu erwähnen, dass dieser Thermograph nicht die wirkliche 10 cm Tiefentemperatur im Boden anzeigte, da trotz der Bedeckung des Apparates mit einem Brett eine Diffusion der Luft über dem Boden mit der um den Thermokörper herum stattfand. Leider standen uns keine Tiefenthermometer zur Verfügung, auch nicht das nötige Personal, um exaktere Beobachtungen zu machen. Für künftige Expeditionen wird sich die elektrische Registrierung in verschiedenen Tiefen empfehlen. Die Thermographen wurden um 7a, 2p und 9p im Falle 1 und 2 mit den Ablesungen des Psychrometers verglichen, im Falle 3 mit denen eines einfachen, nicht aspirierten Thermometers; ausserdem wurden zum Vergleich die Beobachtungen der Extremthermometer, welche sich neben jedem Thermokörper befanden, herangezogen. Die Kolumnen 6, 8, 10 der Tabelle 3 zeigen den täglichen Gang für die drei aus den Kurven erhaltenen Temperaturen.

Das Mittel der *Lufttemperatur* (Engl. Hütte) beträgt nach den Aufzeichnungen vom 2.—11. Oktober: 13°.0 C, die mittlere Amplitude 10°.5, indem wir ein mittleres Maximum von 19°.0 und ein mittleres Minimum von 8°.5 finden. Die grösste Schwankung zeigt sich am 7. mit 21°.8, die kleinste am 10., dem Tage der Sonnenfinsternis, mit 0°.8 (Kol. 5, Tab. 3). Der tägliche Gang weist nichts Bemerkenswertes auf, mit Ausnahme vielleicht einer Verzögerung des Anstiegs der Temperatur. Bei den *Temperaturen*, die *über dem Boden* (Mittel 3.—11. Okt. 12°.6) registriert wurden, ist die Verzögerung noch deutlicher, sie geht sogar in eine kleine Depression über, die *zeitlich* mit der stärker ausgeprägten der Strahlungstemperatur zusammenfällt und von ihr *abhängig* sein dürfte. Die Amplitude ist auffallenderweise über dem Boden geringer und beträgt (3.—11. Okt.) 8°.8 C; dies ist wohl dadurch zu erklären, dass die Beobachtungstage kaum einmal einen reinen Strahlungstyp darbieten, die Hälfte der Tage sogar stark bewölkt ist, und dass vor allem der Boden andauernd durchfeuchtet ist. Das Maximum tritt über dem Boden trotzdem etwas früher ein (2p) als in der Englischen Hütte (3p); die Minima fallen zusammen. Ein feuchter Boden wird natürlich bei Sonnenfinsternissen für ähnliche Untersuchungen sehr störend sein. In 10 cm Tiefe (Mittel 8.—11. Oktober 15°.1) finden wir einen stark abgeflachten Gang der Temperatur, wobei nicht zu übersehen ist, dass hier nur die vorwiegend trüben und regnerischen Tage vom 8.—11. Oktober Beobachtungen aufweisen. Für die Periode haben wir in 10 cm die Amplitude 3°.4, über dem Boden die doppelte mit 6°.7 und in der Hütte eine gleiche von 6°.8. In 10 cm. Tiefe finden wir besonders das Minimum

stark heraufgerückt, 13°.2, während das Maximum für den betreffenden Zeitraum (8.—11 Oktober) ebenso hoch wie das in der Hütte, d. h. 16°.6 (resp. 16°.5), und einen Grad höher wie das über dem Boden, 15°.6, ist.

Relative und absolute Feuchtigkeit. Den Verlauf der relativen Feuchtigkeit zeigen die Kolumnen 12, 14 und 16 (Tabelle 3). Die drei Hygrographen waren neben den Thermographen aufgestellt; die Apparate in der Hütte und über dem Boden wurden um 7a, 2p und 9p mit dem Aspirationspsychrometer verglichen, der im Boden nur einmal am Tage. Wir haben einen Mittelwert der relativen Feuchtigkeit in der *Hütte* (2.—11. Oktober, von 80 Prozent, ein Maximum von 90 Prozent und ein Minimum von 28 Prozent, *über dem Boden* ein höheres Mittel (3.—11. Oktober) von 84 Prozent, ein Maximum von 100 Prozent und ein Minimum von 33 Prozent. Auffallend ist die häufig starke Differenz in den Einzelwerten „Boden" und „Hütte". Bei luftelektrischen Untersuchungen müsste also gefordert werden, dass die meteorologischen Ablesungen neben dem Elektroskope erfolgen, was nicht immer geschieht, und auch bei uns nicht der Fall war. Derartige Differenzen beweisen ferner, dass schon leichte Windströmungen elektrische Zustände aus der näheren Umgebung mit anderer klimatischer Charakteristik herantragen können. *Im Boden* herrscht, dank der Durchfeuchtung, eine sehr geringe Amplitude und ein hoher Mittelwert von 94 Prozent (8.—11. Oktober). Auch die *absolute* Feuchtigkeit (s. Tab. 3, Kol. 18, 20 und 22) ist hier natürlich am höchsten: 12.0 mm gegen 8.9 mm (Hütte) und 9.1 mm (Boden). Die Amplituden sind resp. 1.7, 2.3, und 1.7 mm. Ihr Maximum fällt in die Abendstunden (8p), während es über dem Boden und in der Hütte auf den Nachmittag trifft. Da die Dampfspannung hier im allgemeinen mit der Temperatur zunimmt, so zeigt der Gang der relativen Feuchtigkeit nur ein abgeschwächtes Spiegelbild des Temperaturverlaufes.

Die Verdunstung. Die Verdunstungswage war in einer zweiten englischen Hütte aufgestellt. Die Verdunstung (s. Tab. 3, Kol. 24) beträgt im Mittel 1.8 mm pro Tag, das Maximum ist 3.6 (unvollständige Registrierung am 1. Oktober), das Minimum 0.1 mm (10. Oktober). Der Anstieg beginnt um 8a, der Höhepunkt wird zwischen 2-4p erreicht.

Der Wind. Die Windfahne war im Hof aufgestellt, die Registrierfahne befand sich 8 m über dem Boden, ihr zur Seite auf einem Pfahl, an dem eine Leiter lehnte, in 5 m Höhe das Anemometer. Da der Hof überaus geräumig war, so war eine Störung durch das Gebäude kaum vorhanden; wohl aber machten sich die allseitig

vorhandenen Höhenzüge geltend, welche den Wind abschnitten. Die Registrierung (s. Tab. 3, Kol. 27 und 28) ist daher wenig bemerkenswert; es herrschte fast andauernd und im Mittel Windstille. Der selten auftretende Wind ist fast immer sehr schwach (B. 1) und nur an einigen Nachmittagen etwas auffrischend. Die Richtung entspricht der aus dem ersten und dritten Quadranten.

Meteorologische Beobachtungen am Finsternistage.

An den meteorologischen Beobachtungen beteiligten sich am 10. Oktober 1912 in wirkungsvollster Weise Herr und Frau Professor H. von Ihering, sowie der Institutsmechaniker W. Trollund (s. Tab. 3, Kol. 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 25 und 26; Tab. 4., Fig. 2).

Die Ablesungen wurden um 8a begonnen und um 1p beendet: sie erfolgten alle 5 Minuten für die Hüttentemperatur, alle 10 Minuten für die Temperatur über dem Boden und in 10 cm Tiefe. Dem Aktinographen wurden die Schwarzkugeltemperaturen für alle 5 Minuten entnommen, dem Barographen Luftdruckwerte für alle 10 Minuten. Beide Registrierapparate wurden, abgesehen von den üblichen Vergleichen, kurz vor 8a und kurz nach 1p durch direkte Ablesungen nachgeprüft; sie funktionierten übrigens tadellos. Direkte Ablesungen der Feuchtigkeiten erfolgten alle 10 Minuten in der Hütte und über dem Boden. In 10 cm Tiefe wurden sie für je 20 Minuten dem Hygrographen entnommen, dessen richtiges Funktionieren vor und nachher durch Vergleiche mit dem Aspirationspsychrometer festgestellt wurde. Die Verdunstungswerte wurden aus der Evaporigraphenkurve gezogen; die Windrichtungen entsprechen den Angaben der registrierenden Windfahne, und zwar für je 10 Minuten; für die Windgeschwindigkeiten erfolgten alle 10 Minuten direkte Ablesungen des Anemometers sowie Schätzungen nach Beaufort.

Wenn auch der 10. Oktober gerade nicht den wünschenswerten, klaren Sonnenfinsternishimmel aufwies, so zeigte das schlechte Wetter immerhin eine relativ günstige Seite. Den ganzen Tag hatten wir, ohne dass die Sonne auch nur einmal hervorguckte, ein überaus gleichmässiges Verhalten der Elemente. Aus einer mittelstarken, einförmig grauweissen, den ganzen Himmel bedeckenden Nimbus-Bewölkung fiel gleichmässiger Landregen. Infolgedessen war der Gang aller in Betracht kommenden Elemente ein ausserordentlich flacher; konvektive Luftbewegungen waren kaum vorhanden. Unter allen Tagen unserer Anwesenheit in Boâ Vista wiesen die Schwarzkugeltemperaturen, Temperaturen in der Hütte,

über dem Boden und in 10 cm Tiefe, ferner die dazu gehörigen relativen und absoluten Feuchtigkeiten am 10. Oktober die kleinsten Werte auf. Dieses Verhalten des Wetters war uns, wenn es den gehegten Wünschen auch nicht entsprach, natürlich weit willkommener, als etwa ein Tag mit zeitweilig sonnigem, unregelmässigem Böentypus. Das gleiche gilt für die luftelektrischen Beobachtungen. Es handelte sich also festzustellen, *ob und wie die Mondbedeckung bei völlig bezogenem Himmel auf die verschiedenen Elemente einwirkte.*

Luftdruck. Leider stand uns kein Statoskop zur Verfügung, das uns gestattet hätte, feinere Luftdruckschwankungen festzustellen. Die Luftdruckkurve vom 10. Oktober 1912 entspricht völlig der normalen. Das Hauptmaximum fällt auf den Beginn der Finsternis. Naturgemäss tritt darauf der zu erwartende normale Abfall ein, der über die Finsternis hinaus bis zum Nachmittagsminimum zwischen 4-5p anhält. *Ein Einfluss der Finsternis auf den Luftdruck war also nicht vorhanden.* Eine Verzögerung in der Abnahme des Luftdrucks, d. h. eine relative Zunahme, fand Budig bei der partiellen Sonnenfinsternis am 17. April 1912 in Norddeutschland.[3] Hingegen scheint eine fallende Tendenz, resp. eine Steigerung in der Abnahme des Luftdrucks, nach Arendt[4] am gleichen Datum in Potsdam bestanden zu haben. Ohne deutliche Einwirkung auf den Druck blieb nach P. Cirera die totale Finsternis in Tortosa[5] am 30. August 1905; zu dem gleichen Ergebnis kam Lüdeling am gleichen Tage in Burgos.[6] Keine Änderung des Luftdrucks wurde nach Corless, Dubson und Chree während der partiellen Sonnenfinsternis am 17. April 1912 in Grossbritannien[7] festgestellt, während Otetelisanu[8] in Rumänien bei der Finsternis am 21. August 1914 eine Stunde nach der grössten Bedeckung ein Minimum und nach 1½ Stunden ein Maximum der Luftdruckänderung beobachtete. Es scheint hiernach, dass, wie schon bei früheren Gelegenheiten, irgend ein Einfluss der Sonnenfinsternis auf den Verlauf des Luftdrucks bisher nicht erhärtet wurde.

[3] W. Budig, Beobachtungen auf dem Brockenobservatorium während der Sonnenfinsternis vom 17. April 1912 in *Veröffl. d. Kgl. Preuss. Meteor. Inst.* No. 256, 1913. S. 78-81. Daselbst auch cit. Verhalten des Luftdrucks bei früheren Sonnenfinsternissen.

[4] Th. Arendt, Luftdruckänderung während der partiellen Sonnenfinsternis am 17. April 1912 zu Potsdam in *Veröffl. d. Kgl. Preuss. Meteor. Inst.* No. 256, 1913, S. 87-91.

[5] R. Cirera. Notas de algunas observaciones del Eclipse del 30 de Agosto de 1905 en las *Memorias del Observatorio del Ebro.* No. 1, 1906, S. 37.

[6] G. Lüdeling und A. Nippoldt.—D. Expedition des Kgl. Preuss. Meteor. Instituts nach Burgos in Spanien zur Beobachtung der totalen Sonnenfinsternis am 30. August 1905 in *Veröffl. d. Kgl. Preuss. Meteorol. Inst.* No. 198, 1908, S. 54 und S. 60.

[7] R. Corless, G. Dobson und C. Chree.—Met. Elect. a. Magn. Observ. during the Solar Eclipse of April 17, 1912, in *Journal of Royal Meteorological Society*, July, 1913, S. 222.

[8] E. Otetelisanu.—La variation de la pression atmosphérique pendant l'éclipse du soleil au 21. août 1914, observé en Roumanie in *Boll. d. l. Section Scientifique de l'Académie Roumaine.* No. 8.—S. 233-238.

TABELLE 4. —*Meteorologische Beobachtungen, Boá Vista, während der Sonnenfinsternis, 10. Okt. 1912.*

M. O. Z. Okt. 10.	Luftdruck 600 mm. +	Temperatur: Strahlungs (S)	Temperatur: In der Hütte (H)	Temperatur: Über d. Boden (B)	Temperatur: 10 cm Tiefe (T)	Temp.-Diff.: S-H	Temp.-Diff.: H-B	Temp.-Diff.: T-B	Rel. Feucht'k: Hütte	Rel. Feucht'k: Ü. d. Boden	Rel. Feucht'k: 10 cm Tiefe	Abs. Feuchtigkeit: Hütte	Abs. Feuchtigkeit: Ü. d. Boden	Abs. Feuchtigkeit: 10 cm Tiefe	Verdunstung	Wind: Richtung	Wind: Geschw. (Beauf.)	Wind: Geschw. m/min
h m	mm	°C	°C	°C	°C	°C	°C	°C	%	%	%	mm	mm	mm	mm			
8 00	79.6	15.7	13.2	13.1	15.1	2.5	+0.1	2.0	97	99	100	11.0	11.9	12.8	0.0	C	0	0
05	...	5.7	3.3	...	...	2.4												
10	9.6	5.7	3.5	3.1	5.1	2.2	+0.4	2.0	93	99	...	10.7	11.1	...	...	C	0	2
15	...	5.7	3.5	...	...	2.2												
20	9.6	5.7	3.5	3.2	5.1	2.2	+0.3	1.9	95	99	100	10.9	11.2	12.8	0.0	C	0	3
25	...	5.7	3.5	...	...	2.2												
30	9.7	5.6	3.4	3.3	5.1	2.2	+0.1	1.8	96	99	...	11.0	11.3	...	...	C	0	9
35	...	5.7	3.4	...	...	2.3												
40	9.7	5.5	3.3	3.4	5.1	2.2	−0.1	1.7	95	98	100	10.8	11.2	12.8	0.0	C	0	7
45	...	5.6	3.3	...	...	2.3												
50	9.7	5.5	3.3	3.4	5.2	2.2	−0.1	1.8	96	98	...	10.9	11.2	...	...	C	0	3
55	...	5.5	3.3	...	...	2.2												
9 00	9.7	5.5	3.3	3.4	5.2	2.2	−0.1	1.8	97	100	100	11.0	11.5	12.9	0.0	C	0	2
05	...	5.6	3.3	...	...	2.3												
10	9.6	5.4	3.5	3.4	5.2	1.9	+0.1	1.8	95	99	...	10.9	11.4	...	...	C	0	9
15	...	5.3	3.4	...	...	1.9												
20	9.6	5.1	3.5	3.2	5.3	1.6	+0.3	2.0	94	97	100	10.8	11.0	13.0	0.0	WNW	1	64
25	...	5.0	3.5	...	...	1.5												
30	9.5	4.9	3.5	3.1	5.3	1.4	+0.4	2.2	92	97	...	10.7	10.9	...	...	WSW	1	38
35	...	4.7	3.4	...	...	1.3												
40	9.4	4.5	3.4	3.2	5.2	1.1	+0.2	2.0	95	98	100	10.9	11.1	12.9	0.0	WSW	1	19
45	...	4.4	3.4	...	...	1.0												
50	9.4	4.3	3.4	2.8	5.2	0.9	+0.6	2.4	94	99	...	10.7	10.9	...	...	WSWzW	2	99
55	...	4.2	3.4	...	...	0.8												
10 00	9.4	4.2	3.4	2.8	5.1	0.8	+0.6	2.3	96	100	100	11.0	11.0	12.8	0.0	C	0	6
05	...	4.2	3.3	...	...	0.9												
10	9.4	4.1	3.3	2.5	5.0	0.8	+0.8	2.5	96	99	...	10.9	10.7	...	...	W	2	109
15	...	3.8	3.3	...	...	0.5												
20	9.4	3.6	3.2	2.4	4.9	0.4	+0.8	2.9	95	98	100	10.7	10.5	12.7	0.0	WNWzN	1	38
25	...	3.6	3.1	...	...	0.5												
30	9.3	3.8	3.0	2.6	4.9	0.8	+0.4	2.3	97	99	...	10.8	10.8	...	...	W	1	49
35	...	4.0	3.0	...	...	1.0												
40	9.3	4.0	3.1	2.7	4.8	0.9	+0.4	2.1	94	100	100	10.5	11.0	12.6	0.0	W	1	18
45	...	4.1	3.1	...	...	1.0												
50	9.2	4.1	3.2	2.9	4.8	0.9	+0.3	1.9	96	99	...	10.8	11.0	...	...	W	1	16
55	...	4.1	3.2	...	...	0.9												
11 00	9.2	4.1	3.3	3.0	4.9	0.8	+0.3	1.9	97	100	100	11.0	11.2	12.7	0.0	W	1	56
05	...	4.1	3.3	...	...	0.8												
10	9.1	4.2	3.3	3.1	4.9	0.9	+0.2	1.8	96	99	...	10.9	11.1	...	...	W	1	31
15	...	4.3	3.3	...	...	1.0												
20	9.1	4.4	3.3	3.2	5.0	1.1	+0.1	1.8	96	98	100	10.9	11.1	12.7	0.0	W	1	33
25	...	4.7	3.3	...	...	1.4												
30	9.0	5.0	3.3	3.3	5.0	1.7	0.0	1.7	96	99	...	10.9	11.3	...	...	C	0	0
35	...	5.4	3.3	...	...	2.1												
40	9.0	5.7	3.2	3.3	5.1	2.5	−0.1	1.8	96	99	100	10.8	11.3	12.8	0.0	WSW	1	30
45	...	5.9	3.3	...	...	2.6												
50	8.8	5.6	3.2	3.3	5.2	2.4	−0.1	1.9	97	98	...	10.9	11.2	...	...	WSW	1	41
55	...	5.5	3.3	...	...	2.2												
Mitt'g	8.8	5.9	3.2	3.5	5.2	2.7	−0.3	1.7	96	100	100	10.8	11.6	12.9	0.0	W	1	72
05	...	6.0	3.3	...	...	2.7												
10	8.7	5.9	3.4	3.6	5.2	2.5	−0.2	1.6	94	99	...	10.6	11.5	...	...	W	1	50
15	...	5.8	3.5	...	...	2.3												
20	8.7	5.8	3.6	3.6	5.1	2.2	0.0	1.5	92	99	100	10.6	11.5	12.8	0.0	WSWzW	1	30
25	...	5.8	3.8	...	...	2.0												
30	8.7	5.7	3.8	3.5	5.2	1.9	+0.3	1.7	94	98	...	11.0	11.3	...	...	W	1	51
35	...	5.7	3.8	...	...	1.9												
40	8.5	5.6	4.0	3.5	5.2	1.6	+0.5	1.7	96	98	100	11.4	11.3	12.9	0.0	W	1	40
45	...	5.5	3.9	...	...	1.6												
50	8.4	5.5	4.0	3.5	5.2	1.5	+0.5	1.7	96	99	...	11.4	11.4	...	...	W	1	29
55	...	5.5	4.0	...	...	1.5												
13 00	8.3	5.5	4.2	3.4	5.2	1.3	+0.8	1.8	96	98	100	11.6	11.2	12.9	0.0	C	0	12

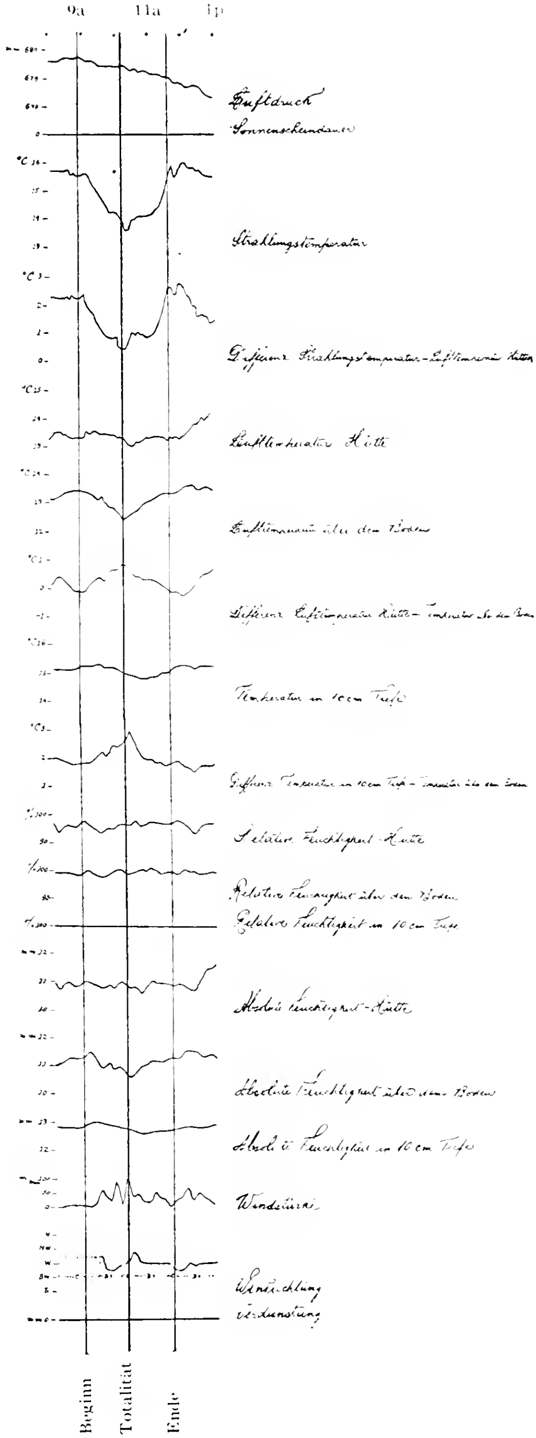


FIG. 2—Finsterniskurve der Meteorologischen Elemente in Boă Vista (Christina), Brasilien, am 10. Oktober, 1912, 8a—1p (s. Tabelle 4).

Strahlungstemperatur. Trotz der Bewölkung ist ein Strahlungseinfluss deutlich bemerkbar; es beträgt nämlich die *infolge der Finsternis eingetretene Depression* 2°.2, ein an sich, im Verhältnis zu den bei heiterem Sonnenfinsternis-Wetter erhaltenen Abnahmen, überaus geringer Wert, der aber in unserem Falle 4½ mal grösser ist als die Abnahme der Temperatur im Schatten. Wir haben, nachdem die Schwarzkugeltemperatur von 13°.5 um 6a auf 15°.7 um 8a gestiegen ist, zunächst eine Konstanz bis $9^h\ 5^m$a, indem die Werte sich zwischen 15°.5 und 15°.7 halten. Es fehlt also noch vor Beginn der Finsternis ($8^h\ 54^m$.5a) der zu erwartende Anstieg und bis 10½ Minuten nach Beginn der zu erwartende Abfall. Wir haben hier wahrscheinlich zwei Umstände, welche wir zur Erklärung heranziehen dürfen. Einmal wirkte eben das Schwarzkugelthermometer bei den Witterungsverhältnissen des Finsternistages nicht als Strahlungsmesser allein; das Instrument blieb auch dem Einflusse der Lufttemperatur ausgesetzt. Während die Strahlung ziemlich unmittelbar auf die Schwarzkugel wirkt, ist der Temperatureinfluss durch den isolierenden luftleeren Raum verzögert. Ferner kommt in Betracht, dass zunächst die Minderung der Strahlung bei der beginnenden Bedeckung der Sonne durch die Zunahme der Strahlung mit steigender Sonne aufgehoben wird. Es darf weiter nicht ausser Acht gelassen werden, dass Unterschiede in der Bewölkungsdichte und- Struktur, so einförmig die ni-Schicht auch dem Auge erschien, hier und bei weiteren kleinen Änderungen in dem Kurvenverlauf mitgewirkt haben können. In gewissem Sinne beobachteten wir ein Strahlungsthermometer im Schatten.[9]

Um $9^h\ 5^m$a beginnt der Abfall um 0°.1 oder 0°.2 pro je 5 Minuten, von $9^h\ 55^m$a bis $10^h\ 5^m$a folgt wieder ein Gleichbleiben der Temperatur (Bewölkung!?), darauf relativ rasch der weitere Abfall bis zum Minimum von 13°.6, welches fast gleich dem des ganzen Tages (13°.5) ist. Das Minimum tritt also erst 6.5 Minuten nach Beginn der Totalität und 4.5 Minuten nach ihrem Ende auf. Das Minimum hält 5 Minuten an, dann erfolgt in ähnlicher Weise der Anstieg, indem von $10^h\ 50^m$a bis $11^h\ 5^m$a die Quecksilbersäule wiederum stehen bleibt, um dann alle 5 Minuten um je 0°.1, danach um 0°.2 oder 0°.3 anzusteigen; um $11^h\ 45^m$a, also rund 4 Minuten nach Ende der Finsternis, sind 15°.9 erreicht; nach einem kleinen Abfall auf 15°.5 folgt um $0^h\ 5^m$p das Maximum des ganzen Tages mit 16°.0. Hieran schliesst sich die früher erwähnte sekundäre, nachmittägliche Depression der Strahlung, die am Finsternistage dank dem Wetter nur sehr schwach ausgebildet ist.

[9] Observ. d. eclipse de sol del 21 agost. de 1914 in Iberica N. 42, S. 249, 1914.

Das während der Finsternis auftretende Schwarzkugelminimum zeigt höhere Werte als das der Lufttemperatur, tritt aber 10 Minuten eher auf. *Die Differenzen Schwarzkugel—Hüttenthermometer* sind fast parallel dem Gang des Schwarzkugelthermometers, sie betragen bei Beginn und Ende der Finsternis rund 2°.5, um zur Zeit des Strahlungsminimums auf weniger als 0°.5 zu sinken. Nach der Finsternis fallen die Differenzen wieder stark, weil die regelmässige, nachmittägliche Depression der Strahlung beginnt, während die Temperatur zu ihrem Maximum ansteigt. Es ist interessant, hieraus zu ersehen, wie relativ stark trotz der Bewölkung die Strahlung vor und nach der Finsternis war, und wie das Bild der Strahlungskurve doch bei kleinen absoluten Änderungen durch die Bedeckung der Sonne beeinflusst wurde.

Temperaturen. Die *Lufttemperatur* (Hütte) weist unter allen beobachteten Temperaturen die geringste Einwirkung der Finsternis auf, und sie zeigt eine völlig anders geartete Kurve als die Strahlungstemperatur und die Temperatur am Boden. Zwischen 8a und $0^h\ 15^m$p, also während der ganzen Finsternis, sowie vorher und nachher, beträgt die Variation nur 0°.5. Wir haben, vor Beginn der Bedeckung bis 15 Minuten nach dem 1. Kontakt, eine schwache Depression, der ein geringes Steigen (um 0°.2) folgt. Dann bleibt die Temperatur ziemlich konstant (13°.5 resp. 13°.4) bis $9^h\ 30^m$a, resp. 10a. Jetzt erst, also ¼ Stunde vor der Totalität, wird der Einfluss der Bedeckung merklich, und die Temperatur sinkt auf das *Minimum* 13°.0, das 0°.7 höher als das Tagesminimum ist. Diese Temperatur tritt um $10^h\ 30^m$a ein, d. h. 16.5 Minuten nach Beginn der Totalität oder mit einer Verspätung von 10 Minuten gegen die Strahlungstemperatur. Wie bei dieser, bleibt das Minimum 5 Minuten lang bestehen. Die Verspätung des Temperaturminimums an sich gegenüber dem Strahlungsminimum ist oft beobachtet worden,[10] gewinnt aber in unserem Falle dank den eigentümlichen Witterungsverhältnissen ein besonderes Interesse.

Es erübrigt sich zu sagen, dass *subjektiv* eine *Abkühlung* bei so geringer absoluter Abnahme der Lufttemperatur und Strahlung nicht zu fühlen war. Nach dem Minimum findet ein stufenförmiges Ansteigen auf 13°.4 um 11a statt. Auf dieser Höhe bleibt das Thermometer bis Mittag, also bis 19 Minuten nach dem 4. Kontakt, ungefähr konstant stehen, um dann ziemlich schnell bis 1 Uhr um einen vollen Grad zu steigen. Der Gang der Lufttemperatur ist entschieden auffallend, besonders im Vergleich zur Strahlungs- und zur Bodentemperatur, welche beide zur Zeit der Verfinsterung

[10] s. BUDIG, l. c. (3), S. 83.

eine ziemliche Parallelität zeigen, die bei der Lufttemperatur völlig fehlt. Wären Strahlungs- und Bodentemperaturen *nicht* beobachtet worden, so wäre es kaum möglich gewesen, einen zweifelsfreien Einfluss der Verfinsterung auf den Stand des Hüttenthermometers festzustellen. Man hätte schliessen können, dass Zunahme der Wolkendichtigkeit die kleine Depression nach der Totalität bedingte, ähnlich wie eine ev. Minderung der Wolkendichte die Zunahme der Temperatur nach 12 Uhr. Gerade die Ablesungen des Schwarzkugelthermometers und des Thermometers über dem Boden zeigen uns aber, dass die Bewölkung, dem subjektiven Eindruck entsprechend, von relativ kleinen Schwankungen abgesehen, eine gleichmässige war.

Der Verlauf der *Bodentemperatur* entspricht der Erwartung. Am Finsternistage (und am Tage darauf) ist die Temperatur über dem Boden etwas niedriger (Niederschlag!) als die in der Hütte (am 10. Oktober um 0°.2). Trotz der sehr starken Durchfeuchtung des lehmigen Bodens folgt die Temperatur der geringen, durch die Wolkendecke so behinderten Insolation im gewissen Sinne noch regelmässiger als die Schwarzkugeltemperatur. Die Kurve erinnert an die trichterförmigen Barogramme bei tropischen Wirbelstürmen. Nach Ansteigen der Temperatur bis ¼ Stunde vor Beginn des 1. Kontakts tritt eine Konstanz der Temperatur ein, für die die Erklärung bereits bei Besprechung der Schwarzkugelablesungen gegeben wurde. Dann beginnt ein langsamer, etwas gestörter Abfall, ohne dass diese Störungen bei den Strahlungstemperaturen vorhanden sind. Die Parallelität wäre vielleicht grösser, wenn die Ablesungen nicht 5.5 cm über, sondern direkt auf dem Boden ausgeführt worden wären. So scheinen gewisse vertikale Luftbewegungen unmittelbar über dem Boden (trotz seiner Durchfeuchtung) einerseits einen gewissen Ausgleich, andererseits kleine Schwankungen in dem Temperaturgange bedingt zu haben. Das *Minimum* tritt wie bei der Schwarzkugeltemperatur 6.5 Minuten nach der Totalität und 10 Minuten vor dem der Lufttemperatur ein, ein Verhalten, das zu erwarten ist. Der aufsteigende Ast ist besonders gleichmässig, und es fehlt die Zeit der Konstanz, die am Schwarzkugelthermometer beobachtet wurde. Wie bei diesem, hält die Zunahme bis 12 Uhr an, worauf die Temperatur, wie im Mittel aller Beobachtungstage, zunächst ungeändert bleibt. Die Erniedrigung der Bodentemperatur beträgt 1° gegenüber der ohne Finsternis zu erwartenden; sie steht zwischen der Finsternisdepression des Hütten- und Strahlungsthermometers. Die *Differenzen Hütte—Boden* sind am geringsten zu Beginn und Ende der Fin-

sternis, wo sogar negative Werte auftreten, d. h. wo die Temperatur am Boden höher ist als die in der Hütte. Mit dem stärkeren Fall der ersteren gegen die Temperatur im Schatten treten naturgemäss die grössten Differenzen auf, ebenso wie nach Schluss der Finsternis dank dem Ansteigen des Hüttenthermometers. Das Maximum dieser Differenzen fällt auf die Zeit der Totalität.

Die *Temperaturen in* 10 *cm Tiefe* sind von der Temperatur über dem Boden abhängig; die Kurve zeigt den zu erwartenden Verlauf, die Amplitude ist abgeflacht und beträgt etwa 0°.5, d. h. sie ist der bei der Hüttentemperatur aufgetretenen Schwankung ungefähr gleich. Zunächst steigt die Temperatur noch sehr langsam: von $8^h\ 45^m$a bis $9^h\ 20^m$a um 0°.2 auf 15°.3, d. h. bis 20 Minuten nach Beginn der Finsternis; erst von $9^h\ 30^m$a beginnt ein langsamer, gleichmässiger Abfall, um mit 14°.8 um $10^h\ 40^m$a., also 26.5 Minuten nach Beginn der Totalität und 20 Minuten nach dem Minimum der Temperatur über dem Boden, den *tiefsten Stand* für 10 Minuten Dauer zu erreichen. Die Verspätung ist hier also am bedeutendsten und wäre vielleicht noch ausgeprägter, wenn bei der Art der Aufstellung der betr. Instrumente nicht eine schon vorher erwähnte, wahrscheinliche Diffusion der Luft die reine Wärmeleitung beeinträchtigt hätte. Von $10^h\ 55^m$a. an beginnt ein langsamer Anstieg von etwa gleicher Form wie vorher der Abfall, um kurz vor Mittag, aber 10 Minuten nach dem letzten Kontakt, in die auch im Mittel (8.—11. Oktober) vorhandene Konstanz der Temperatur überzugehen.

Die *Differenzen, Temperatur* 10 *cm Tiefe-Bodentemperatur* geben ungefähr ein Spiegelbild der letzteren. Kurz nach der Totalität tritt der grösste Unterschied mit fast 3° auf, gegen 1°.8 im Mittel des 10. Oktober.

Feuchtigkeit. Die relative Feuchtigkeit zeigt hohe Werte: in der Hütte schwankt sie unregelmässig während der Finsternis um 95 Prozent herum, *über dem Boden* gleichfalls unregelmässig zwischen 97 und 100 Prozent, in 10 *cm* Tiefe herrscht während der ganzen Beobachtungszeit Sättigung. *Ein Einfluss der Finsternis auf die relative Feuchtigkeit ist nicht vorhanden.*

Da bei den Temperaturen ein Einfluss festgestellt wurde, so folgt, dass bei unbeeinflusster, relativer Feuchtigkeit eine Erniedrigung des Dampfdrucks zu erwarten ist, da bei gleichbleibendem oder gar steigendem Wasserdampfgehalt der Luft die relative Feuchtigkeit während der Finsternis ansteigen würde. Bei dem regnerischen Wetter und dem feuchten Erdreich war Wasser zur Ansättigung reichlich vorhanden, es mussten daher ungefähr die Maximalspan-

nungen des Wasserdampfes auftreten und diese mit fallender Temperatur gleichfalls abnehmen. Ein derartiges Verhalten lässt sich auch erkennen. Bei der *absoluten Feuchtigkeit* der *Hütte* finden wir wie bei der entspr. Temperatur geringe Änderungen während der Finsternis, doch tritt nach der Totalität, ähnlich wie bei der Temperatur, eine Finsterniszacke von 0.5 mm auf. Nach dem Ereignis beobachtet man entsprechend der Schattentemperatur ein rasches Ansteigen der Spannungswerte. Im einzelnen finden sich hier und auch bei der Feuchtigkeitskurve über dem Boden ziemlich beträchtliche Schwankungen.

Wie bei der Temperatur *über dem Boden*, ist die dazu gehörige Dampfspannung eine weit ausgesprochenere als in der Hütte (4 mm Abfall!). In 10 *cm Tiefe* haben wir eine fast parallele, nur abgeschwächte Kurve der absoluten Feuchtigkeit zur Temperatur; bei völliger Sättigung fehlen hier auch grössere Einzelschwankungen (Abfall 0.4 mm). In allen diesen Fällen treten die Spannungsminima ungefähr mit den tiefsten Thermometerständen gleichzeitig auf.

Die Trübwetter- und Regensonnenfinsternis zeigt also einen zweifelsfreien Einfluss auf den Gang der Dampfspannung, wie er bei ähnlichen Ereignissen andernorts nicht immer zutage getreten ist. Budig[11] fand keine Änderung der absoluten Feuchtigkeit und entsprechend eine geringe Erhöhung der relativen Feuchtigkeit, ein Resultat, das mit dem Cireras[12] übereinstimmt. Lüdeling[13] fand eine Zunahme beider Feuchtigkeiten. Es ist aber wohl anzunehmen, dass die Vermehrung der absoluten Feuchtigkeit in Burgos nicht mit der Finsternis zusammenhing, zumal der Beobachtungstag eine starke Störung durch eine während der Finsternis einsetzende Böe zeigte. Mit unseren Ergebnissen stimmen hingegen die Beobachtungen Bigelows gut überein.[14]

Verdunstung. Bei dem während der Finsternis herrschenden Niederschlag und der hohen Feuchtigkeit fand, wie zu erwarten, überhaupt keine Verdunstung während derselben statt. Bei heiterem, sehr trocknem Wetter wäre theoretisch eine leichte Erhöhung der Verdunstung (bei einer im Schatten aufgestellten Wage) infolge der Bedeckung der Sonne zu erwarten. Die Verdunstung ist etwa proportional der Differenz E-e, worin E der Maximalspannung der Temperatur der verdunstenden Flüssigkeitsoberfläche entspricht und konstant bleiben dürfte, während e, der Dampfspannung der Luft entsprechend, kleiner wird.

[11] s. BUDIG, l. c. (3), S. 84. [12] s. CIRERA, l. c. (5), S. 37. [13] s. LUEDELING, l. c. (6), S. 00.
[14] BIGELOW (cit. BUDIG)—Eclipse Meteorology, Science 16, 1902, S. 74.

Wind. Vor der Finsternis herrscht Windstille; erst eine halbe Stunde nach ihrem Beginn kommt eine sehr schwache Luftströmung aus westlichen Richtungen (von West-Nord-West bis West-Süd-West schwankend) auf, die zweimal je eine viertel Stunde von Windstille unterbrochen wird und bis 1 Stunde nach dem letzten Kontakt anhält. Die Windstärke ist B. 1 und nur einmal, gerade zur Zeit der Totalität, B. 2. Die Windgeschwindigkeit in Metern bestätigt das Resultat. Sie wechselt ziemlich bedeutend in kurzen Intervallen, zeigt aber im allgemeinen einen Anstieg bis zur Totalität, wo ein Maximum von 109 m min eintritt; darauf folgt ein rasches Schwanken der Geschwindigkeit, bis gegen 1 Uhr wieder Windruhe einsetzt. Nach diesen Ergebnissen scheint es, als ob trotz der Trübung, trotz der Konstanz im Gange des Luftdrucks und des geringen absoluten Temperaturabfalls ein *Finsterniswind* wenigstens *angedeutet* ist. Eine ausgesprochene *Winddrehung* tritt hingegen nicht auf.

Die subjektive Lichtabnahme. Erst um $9^h\ 27^{m}$a, also 32—33 Minuten nach Beginn der Bedeckung der Sonne durch den Mond, begann ein zunächst kaum merkbares Dunklerwerden (Beobachtungen Knoche), das etwa bis $9^h\ 35^{m}$a (8 Minuten) anhielt, darauf wurde das Dunklerwerden merkbarer, doch nahm die Helligkeit immer noch langsam ab; ohne Übergang wurde es nach weiteren 31 Minuten rasch sehr dunkel, so dass um $10^h\ 6^{m}$a Licht zur Beobachtung (elektr. Taschenlampe) eingeschaltet werden musste. Zwischen $10^h\ 12^{m}$a. und $10^h\ 15^{m}$a. wurde das Maximum der Dunkelheit erreicht, während dieser 3 Minuten, von denen 1.5 Min. vor der Totalität lagen, schien die Intensität sich nicht zu ändern. Unmittelbar nach der Totalität nahm die Helligkeit schnell zu, doch wurde bis $10^h\ 19^{m}$a Licht benutzt.

Künstliche Beleuchtung musste also 11 Minuten lang bei der Ablesung der Elektroskop-Mikroskope angewandt werden, d. h. 7.5 Minuten vor bis 3.5 Minuten nach der Totalität. Nach Löschen des Lichts wurde es sehr rasch hell, darauf folgte eine Zeit relativer Konstanz, dann erst, nach 50 Minuten ($11^h\ 9^{m}$a), ein neues Aufhellen und scheinbar stufenförmig um $11^h\ 15^{m}$a und $11^h\ 28^{m}$a ein weiteres. Um diese Zeit schien ein Einfluss der Finsternis nicht mehr vorhanden zu sein; es war bedeutend heller wie zu Beginn des Ereignisses (höher stehende Sonne). Die letzten Minuten vor dem letzten Kontakt wurden anscheinend durch das Aufziehen etwas dichterer Bewölkung gestört, welche eine leichte Verdunklung herbeiführte. Änderungen in der Bewölkungsdichte mögen überhaupt auf das subjektive Empfinden der Helligkeit

neben der Sonnenbedeckung etwas mitgewirkt haben, wenn auch im Mittel Bewölkungsstärke 1 (Skala 0—2) dauernd bestand.

Um ¾ 6 abends (d. 10. Oktober) musste Licht angezündet werden, d. h. diese Zeit der späten Dämmerung entsprach ungefähr der während der Finsternis um $10^h\ 6^m a$ herrschenden. Der grössten Dunkelheit kurz vor und während der Totalität ($10^h\ 12^m a$ bis $10^h\ 15^m a$) entsprach das spätere Dämmerungsdunkel um 6¼ abends. Während der Finsternis trat also Nachtdunkelheit nicht ein. Diese wurde einige Minuten nach 7p erreicht.

Bei der obigen Schilderung der Lichtabnahme und der nach der Totalität folgenden Lichtzunahme spielt übrigens u. a. zweifellos der psychologische Faktor eine Rolle. Wir sehen, dass vor allem die sehr langsame Zunahme der Dunkelheit gegenüber dem raschen Aufhellen auffällt.

Im Anfang konstatieren wir überhaupt noch keine Verdunklung; die zu Beginn der Finsternis herrschende Helligkeit bleibt konstant, da die Bedeckung (siehe Strahlungskurve) durch die steigende Sonne kompensiert wird. Allmählich überwiegt die Bedeckung; da die Dunkeladaptation des Auges aber sehr langsam vor sich geht, muss relativ früh künstliches Licht benutzt werden. Das Maximum der Dunkelheit tritt schon vor der Totalität ein und scheint bis zum dritten Kontakt konstant zu bleiben. Es könnte die langsame Adaptation bei noch nicht völlig erreichter Totalität durch die objektiv fortschreitende Verdunklung kompensiert werden. Hierdurch ist die beschriebene subjektive Konstanz des Maximums der Finsternis möglicherweise zu erklären. Andererseits besteht bei dem Übergang aus der Dunkelheit ins Helle eine erhöhte Erregbarkeit der Netzhaut und die objektiven Reize werden einen stärkeren Effekt hervorrufen; so erklärt sich das Gefühl sehr starken Hellerwerdens nach der Totalität. Da auch die Helladaptation schneller vor sich geht als die Dunkeladaptation, ist es verständlich, dass das künstliche Licht nach der grössten Bedeckung viel eher entbehrt werden kann (nach weniger als der halben Zeit), als es vor der Totalität benötigt wurde. Selbst verhältnismässig rasch vorübergehende Beleuchtungswechsel lösen adaptive Fähigkeiten aus; es ist somit keine Frage, dass letztere eine grosse Rolle bei der subjektiven Finsternis-Helligkeitskurve spielen. Von Wichtigkeit ist noch die Tatsache, dass beide Adaptationen im Anfang rascher, später langsamer, wenn auch dauernd stetig verlaufen. Hieraus erklärt sich, vielleicht bis zu einem gewissen Grade auch psychologisch, die zunächst sehr langsame Zunahme der Dunkelheit.

Es wäre wünschenswert, dass bei späteren Sonnenfinsternis-

beobachtungen, exakte psychologische Messungen über die Einwirkung der optischen Reize während der Bedeckung angestellt werden, ganz besonders wenn es möglich wäre, gleichzeitig objektive Lichtkurven mittelst Selen- oder Rubidiumzellen zu erhalten. Die Dauer der Finsternis wäre dann von ausschlaggebender Bedeutung besonders für die subjektiven Helligkeitswerte. Tritt doch z. B. völlige Dunkeladaptation erst nach 20 Minuten Dauer ein. Auch die Individualität spielt eine grosse Rolle, besonders das Lebensalter. Bei jugendlichen Personen ist der Unterschied zwischen der Schnelligkeit beider Adaptationen viel ausgeprägter, sie adaptieren in der Dunkelheit langsamer als ältere Leute, aber in höherem Grade.[15]

ANHANG 1.

Bemerkungen über das Verhalten der Tierwelt. Alle Teilnehmer der Expedition widmeten sich der Aufgabe, die Vertreter der Tierwelt, soweit sie im Umkreis der Facenda vorhanden waren, zu beobachten:

h m	
9 45a.	Unter den Tieren ist keine auffällige Bewegung zu bemerken.
9 55.	Vor dem Haus werden als erste die Singvögel, unter ihnen der häufige Tachyphonus coronatus, unruhig, man hört sie aufgeregt zwitschern. Vereinzeltes Krähen der Hähne. Unter dem Rindvieh herrscht eine gewisse Bewegung; es setzt sich gegen den Gutshof hin in Marsch.
10 3.	Die Schwalben fliegen unruhig umher und umkreisen das Haus in kurzen Bögen. Rindvieh und Pferde sammeln sich auf dem Hofe, wo sie bewegungslos unter den Bäumen stehen.
10 5.	Ein Kolibri flattert scheinbar ängstlich oder überrascht umher. Die Schwalben sammeln sich auf der Dachkante und suchen ihre Nester auf. Die Hühner piepsen besorgt und sammeln sich vor der Küche. Alle Hunde befinden sich im Küchenraum. Die Schweine eilen in beschleunigtem Tempo einen Bergpfad herunter auf das Haus zu.
10 12.	Das Verhalten der Tiere bleibt ungeändert.
10 16.	Die Spannung, die auf der Tierwelt lastete, scheint nachzulassen.
10 22.	Die Schwalben verlassen das Dach, die Hühner zerstreuen sich auf dem Hofe, die Hunde geraten in Bewegung, und auch die Schweineherde zieht wieder ab. Das Rindvieh und die Pferde verhalten sich ungeändenr.
11 2.	Nachdem die Pferde zur Weide zurückgekehrt sind, folgt ihnen zuletzt das Rindvieh.

Herr v. Ihering fasste diese Eindrücke etwa wie folgt zusammen:

"Die Tierwelt verhielt sich wie bei einer vorzeitig hereingebrochenen Nacht. So suchten die Schwalben ihre nächtlichen Ruheplätze auf, die Hühner würden sicherlich die ihnen als Nachtlager dienenden Bäume erreicht haben, wenn die Dauer der Finsternis eine grössere gewesen wäre. Die Rückkehr des Viehs zu der ungewohnten Stunde war auffallend; gewöhnlich geschah dies erst um 5p. Während die Heimkehr der Rinder sich in gemessenem Tempo und relativ früh vollzog, eilten die Schweine erst nach Anbruch starker Dunkelheit in so überstürzter Hast dem Hofe zu, dass es geradezu komisch wirkte. Die Tiere liefen nicht nur, sondern wetteiferten unter Stossen und Drängen, nach Haus zu kommen.

"Es ist ein interessantes und zur Zeit unlösbares Problem, auf welche Weise die Verständigung der Herde, das Fassen des Entschlusses zur Rückkehr und seine Mitteilung innerhalb der Herde erfolgt. Die Tiere weideten teilweise in beträchtlicher Entfernung voneinander, und keine Lautäusserung (Signal) war zu vernehmen. Es ist nicht zu entscheiden, so bemerkenswert die Tatsachen sind, ob eine Verständigung vorhanden war, oder ob jedes einzelne Tier, unabhängig vom anderen, unter gleichen Impulsen handelte. Interessant wäre es, weitere Beobachtungen der Tierwelt bei einer länger dauernden Finsternis, wo alle Einwirkungen in gesteigertem Masse zum Ausdruck kommen würden, anzustellen."[16]

[15] W. WUNDT, *Grundzüge d. physiol. Psychologie*, Bd. II, 1910. S. 177-178.

[16] CIRERA, l. c. (5), S. 40.

Anhang 2.

Temperaturbeobachtungen während der partiellen Sonnenfinsternis am 10. Oktober 1912 in Santa Rosa de Los Andes (Chile).

An einer Anzahl von chilenischen meteorologischen Stationen wurden während der am 10. Oktober 1912 eintretenden Sonnenfinsternis Temperaturbeobachtungen vorgenommen. Leider war die Witterung (wechselnde, die Sonne während der Finsternis dauernd oder teilweise bedeckende Bewölkung) sehr ungünstig; nur die Station Los Andes wies allerdings vorzügliche Bedingungen auf, nämlich wolkenfreien Himmel. Der Wind wehte während der ganzen Beobachtungszeit aus WSW mit Stärke *2B.*, von Calmen unterbrochen.

Die partielle Sonnenfinsternis begann in Los Andes ($\phi = 32°$ $50'$ S, $\lambda = 70° \ 36'$ W, $H = 820$ m) um $7^h \ 8^m$a und endete um 9^h 4^ma. Ablesungen während der Finsternis (alle 5 Minuten) am trocknen Hüttenthermometer eines Augustschen Psychrometers wurden von dem meteorologischen Beobachter Herrn M. R. Salas von $6^h \ 40^m$a bis $9^h \ 35^m$a vorgenommen. Die folgende Tabelle 5 enthält die *Temperaturwerte* (s. Fig. 3).

Tabelle 5.—*Temperaturbeobachtungen während der partiellen Sonnenfinsternis in Santa Rosa de Los Andes am* 10. *Oktober* 1912.

Zeit	Temperatur	Zeit	Temperatur	Zeit	Temperatur	Zeit	Temperatur
h m	°C	h m	°C	h m	°C	h m	°C
6 00a	9.6	7 30a	14.4	8 10a	14.6	8 50a	16.2
6 40	12.6	7 35	14.4	8 15	14.4	8 55	16.4
6 50	13.2	7 40	14.6	8 20	14.8	9 00	16.8
7 00	13.8	7 45	14.6	8 25	14.8	9 05	17.2
7 10	14.2	7 50	14.8	8 30	15.0	9 15	17.8
7 15	14.4	7 55	14.6	8 35	15.4	9 25	18.2
7 20	14.4	8 00	14.4	8 40	15.8	9 35	18.8
7 25	14.4	8 05	14.8	8 45	16.0	10 00	20.2

Sie zeigt einen recht beachtenswerten Verlauf, der aller Wahrscheinlichkeit nach wohl durch die Bedeckung der Sonne, welche ein Maximum von 0.4 erreichte, bedingt ist. Zunächst normaler, rascher Anstieg der Temperatur, der aber schon 5 Minuten nach Eintritt aufhört, darauf 20 Minuten unveränderter Stand der Quecksilbersäule, 15 Minuten lang erneutes Steigen um 0°.4, dann rasch aufeinander folgender, zweimaliger Abfall und Aufstieg, von dem gleichen Betrag, und gleich darauf, aber noch 40 Minuten vor Schluss der Finsternis, normales, rapides Weitersteigen der Temperatur.

Es findet also im grossen und ganzen nur eine *Verzögerung*

von 1¼ *Stunde,* welche dem Beginn der Finsternis folgt, *in dem normalen raschen Morgenanstieg der Temperatur* bei heiterem Wetter statt. Die durch die Verfinsterung bedingte Abkühlung wird auch hier durch den raschen Anstieg der Sonne kompensiert; da die Bedeckung aber nur gering ist, kommt es nicht zu einem Abfall; im Gegenteil ist die Vermehrung der Temperatur durch Strahlungsvermehrung beim Höhersteigen des Tagesgestirns gegen Schluss der Erscheinung völlig ausschlaggebend. Die kleinen Schwankungen während der Verzögerung sind wohl durch vertikale Luftströmungen, die, an den Hängen der Kordillere an sich sehr lebhaft, durch die Finsternis wohl eine Auslösung erfahren haben, bedingt.

Die *Feuchtigkeitsbeobachtungen* wurden in Los Andes mit einem Augustschen Psychrometer ausgeführt. Die alle 5 Minuten angestellten Ablesungen enthält die folgende Tabelle 6 (s. auch Fig. 3).

Beide Feuchtigkeiten zeigen kleinere und grössere Schwankungen, doch ist bei der *Dampfspannung* (8 bis 9.5 mm) ein Einfluss der partiellen Finsternis kaum oder *nicht deutlich vorhanden*; hingegen scheint die *Verzögerung im Abfall der relativen Feuchtigkeit* der der Temperatur im Aufstieg zu entsprechen, infolgedessen durch die, wenn auch nur geringe Bedeckung der Sonne bedingt zu sein.

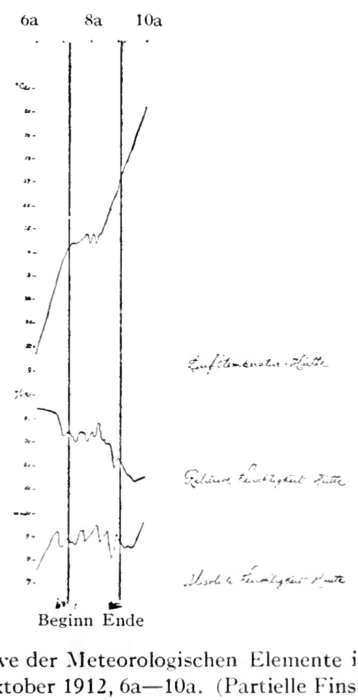


FIG. 3—Finsterniskurve der Meteorologischen Elemente in Santa Rosa de Los Andes, Chile, 10. Oktober 1912, 6a—10a. (Partielle Finsternis; s. Tabelle 5.)

TABELLE 6.—*Feuchtigkeitsbeobachtungen während der partiellen Sonnenfinsternis am 10. Oktober 1912 in Santa Rosa de Los Andes (Chile).*

Zeit	Absol. Feucht.	Relat. Feucht.	Zeit	Absol. Feucht.	Relat. Feucht.	Zeit	Absol. Feucht.	Relat. Feucht.
h m	mm	%	h m	mm	%	h m	mm	%
6 00a	7.5	84	7 45a	9.2	74	8 40a	9.3	69
6 40	9.0	83	7 50	8.8	70	8 45	8.7	64
6 50	9.2	81	7 55	8.9	72	8 50	8.1	59
7 00	8.6	73	8 00	9.0	74	8 55	8.5	61
7 10	8.9	74	8 05	9.1	72	9 00	9.0	63
7 15	8.8	72	8 10	8.9	72	9 05	8.8	60
7 20	8.8	72	8 15	9.5	78	9 15	8.5	56
7 25	8.6	70	8 20	9.1	72	9 25	8.6	55
7 30	8.6	70	8 25	8.8	70	9 35	8.5	53
7 35	9.0	74	8 30	9.0	71	10 00	9.6	55
7 40	9.2	74	8 35	9.0	69			

ZUSAMMENFASSUNG DER METEOROLOGISCHEN BEOBACHTUNGEN.

Kurz zusammengefasst, hat unsere Expedition nach Brasilien zur Beobachtung der totalen Sonnenfinsternis des 10. Oktober 1912 in Boã Vista die folgenden meteorologischen Ergebnisse gehabt:

Es zeigte bei völlig bewölktem Himmel und dauerndem Niederschlag in Folge der Bedeckung der Sonne durch den Mond:

1. der Luftdruck keinen Einfluss,
2. die Strahlungstemperatur eine absolut kleine, aber sehr ausgesprochene depressive Wirkung,
3. die Lufttemperatur ein kaum merkbares Herabgehen,
4. die Temperatur über dem Boden ein deutliches, absolut allerdings geringes Absinken, bei Eintritt des Minimums (wie auch bei 2 und 3) fast unmittelbar nach der Totalität,
5. die Temperatur in 10 cm Tiefe einen schwachen, aber gut merkbaren Abfall, dessen Minimum etwas verspätet der grössten Bedeckung folgte,

6., 7., 8. die relative Feuchtigkeit in der Hütte, über dem Boden und in 10 cm Tiefe keine bemerkbare Änderung,

9. die Dampfspannung in der Hütte eine kaum merkbare,
10. die über dem Boden eine ziemlich deutliche,
11. die in 10 cm Tiefe eine sehr kleine, aber sichtliche Tendenz zur Abnahme, bei ungefähr gleichzeitigem Eintritt der Minima mit denen der Temperaturen,
12. die Windrichtung kaum eine Einwirkung, die Windstärke die Andeutung eines Finsterniswindes, und
13. die Verdunstung keine Einwirkung.

MAGNETIC OBSERVATIONS AT DE BILT RELATING TO THE SOLAR ECLIPSE OF AUGUST 21, 1914.

By G. van Dijk.

According to Dr. Bauer's circular of June 23, 1914, the following is a report on the observations at De Bilt (52° 06′ N, 5° 11′ E) during the solar eclipse of August 21, 1914. A method of illumination (see *Terr. Mag.*, vol. 15, 1910, p. 31), differing from the usual one, is applied for the Adie-magnetograph. A contact clock closes the circuit of a battery for two seconds every minute, the current lights a little glow-lamp and thus forms a small line or spot, about 1/2 mm. long and 1/8 mm. wide, on the paper. The recorded curve consists of a series of points 1/4 mm. apart; the time scale is 15 mm. to the hour. By this method of registration the variations may be followed exactly from minute to minute; the values of D, H and Z, from 10^h-15^h in Table 1 have been derived from the Adie-magnetograms.[1] Care was taken that on the day of the eclipse the moment of the contacts was at zero second Greenwich mean time. The value of 1 mm. was:

$$D : 1'.05 \qquad H : 3.32\gamma \qquad Z : 5.45\gamma$$

Moreover eye-readings of declination and horizontal intensity were taken every minute from 10^h to 15^h; these values were in good agreement with the magnetograph records.

Chree has published[2] a table giving the hourly magnetic data of H and D observed at Kew Observatory (51° 28′ N, 0° 19′ W) on August 21, 1914, and of the mean for 6 adjacent days (August 18, 19, 20, 22, 24, 25). In Table 2 are given the corresponding values for De Bilt, as also those for August 22 (the adjacent "calm" day), and the means for the five "calm days" of the month (August 9, 10, 14, 16, 22). From the tables and from a graphical representation it is evident that the corresponding values for Kew and De Bilt agree well, and that on August 21, between 8^h and 14^h, the values of D are smaller than on August 22 and than the means for the groups of days; for H no special difference is shown. The difference for D is of about the same order $(0-2')$ as at the time of the solar eclipse of April 17, 1912, when the central line was about 125 km. southeast of De Bilt. On August 21, 1914, the central line was about 1300 km. east of De Bilt.

[Referring to Fig. 4, p. 82, *Terr. Mag.*, June, 1916, it was found, when plotting the De Bilt D-values, that the progression in the times when the marked bay occurred is confirmed by the De Bilt curve. The lowest part of the bay was at De Bilt at $12^h\ 09^m$ G. M. T., thus falling between the times for Kew ($12^h\ 01^m$) and Rude Skov ($12^h\ 15^m$), in accordance with the respective times of maximum obscuration at the three stations.—L. A. B.]

[1] The author's original table gave the values for every minute; only the five-minute means are published, however, in order to make possible a direct comparison with the tables in *Terr. Mag.*, vol. 16, 1916, pp. 57-78.—Ed.

[2] *Terr. Mag.*, vol. 15, 1915, p. 73.

TABLE 1.—*Results of Magnetic Observations at De Bilt on August 21, 1914.*

G.M.T.	*D*	*H*	*Z*	G.M.T.	*D*	*H*	*Z*	G.M.T.	*D*	*H*	*Z*
h m	° ′	γ	γ	h m	° ′	γ	γ	h m	° ′	γ	γ
10 01	12 22.3	18479	43164	11 45	12 24.9	18510	43159	13 25	12 26.2	18504	43168
05	22.0	473	164	50	24.7	510	159	30	25.8	501	168
10	22.4	474	164	55	24.6	508	160	35	25.7	502	168
15	23.1	477	165	12 00	24.5	507	159	40	25.3	500	169
20	23.9	479	166	05	24.3	505	160	45	25.0	503	168
25	23.9	480	166	10	23.9	504	160	50	25.3	504	168
30	23.7	479	165	15	24.5	506	162	55	25.2	504	168
35	23.4	479	165	20	24.8	507	162	14 00	25.6	505	168
40	23.4	481	164	25	25.5	508	163	05	25.3	504	169
45	23.5	484	163	30	26.1	508	164	10	24.8	504	169
50	23.7	488	165	35	26.7	509	165	15	25.3	509	170
55	24.3	493	164	40	26.8	509	165	20	25.4	510	171
11 00	24.7	497	163	45	26.8	507	166	25	24.9	510	173
05	24.6	498	162	50	26.8	507	167	30	24.8	511	173
10	24.5	499	163	55	27.0	506	167	35	24.7	511	173
15	24.6	502	162	13 00	27.2	507	167	40	24.1	511	173
.20	24.6	503	162	05	27.2	507	167	45	23.8	511	173
25	24.7	505	160	10	27.1	506	168	50	23.7	513	173
30	24.9	505	159	15	27.1	506	168	55	23.3	513	174
35	24.8	507	160	20	26.6	504	168	14 59	23.0	514	174
40	24.8	508	160								

TABLE 2.—*Hourly Magnetic Data at De Bilt for August, 1914.*

G.M.T.	West Declination				Horizontal Intensity			
	August 21	August 22	Mean for August 18, 19, 20, 22, 24, 25	Mean for calm days, 9, 10, 14, 16, 22	August 21	August 22	Mean for August 18, 19, 20, 22, 24, 25	Mean for calm days, 9, 10, 14, 16, 22
h	° ′	° ′	° ′	° ′	γ	γ	γ	γ
0	12 22.5	12 21.3	12 19.7	12 20.9	18520	18519	18520	18518
1	20.0	20.2	20.5	20.2	520	517	520	518
2	20.6	20.1	20.9	20.1	508	513	515	516
3	18.6	20.8	19.5	19.8	513	505	510	512
4	20.2	20.5	19.4	19.8	507	510	512	514
5	19.9	20.0	18.3	19.0	505	506	512	514
6	19.7	18.0	17.3	18.0	504	504	507	509
7	18.3	17.8	16.6	18.0	496	489	498	497
8	17.3	17.7	17.8	17.9	492	483	490	489
9	18.2	20.7	19.9	20.1	488	486	485	486
10	22.4	23.6	22.9	23.1	481	494	486	489
11	24.7	26.4	25.6	24.9	497	497	489	493
12	24.5	27.9	28.0	26.9	507	497	502	501
13	27.1	27.5	29.0	27.1	507	507	509	509
14	25.6	25.8	27.4	26.2	505	513	511	510
15	23.0	22.8	25.0	24.4	514	524	516	513
16	21.5	21.0	23.3	23.1	523	523	516	517
17	20.5	19.9	21.4	22.0	504	523	518	522
18	20.9	20.0	20.8	21.7	517	520	521	524
19	21.0	20.8	20.9	21.5	519	518	523	523
20	21.1	20.7	19.4	21.2	517	513	521	522
21	20.8	20.7	20.5	21.5	515	514	519	521
22	20.7	21.0	20.2	20.7	513	514	519	521
23	22.2	20.5	19.9	21.1	519	509	522	518
24	21.3	20.5	19.0	20.6	519	512	518	519

RESULTS OF GEOGRAPHIC AND MAGNETIC SURVEY OF THE SOUTHERN PART OF BRAZIL, 1913–15.[1]

No.	Station	Date	Latitude South	Longitude[2] West of Greenwich	Magnetic Elements: Decl'n	Magnetic Elements: South Incl'n	Magnetic Elements: Hor. Int.
			° ′ ″	° ′ ″	° ′	° ′	γ
1	Barra do Pirahy	1913.47	22 27 57	43 49 40	9 51.4W	14 18.2	24634
2	Rezende	.50	22 28 27	44 26 51	9 29.5W	13 48.7	24596
3	*Queluz*	.52	22 26 05	44 46 39	8 49.6W	13 41.9	24587
4	*Quaratinguetá*	.54	22 52 31	45 13 25	8 47.2W	14 08.5	24612
5	*Taubaté*	.55	23 01 12	45 33 15	8 38.2W	14 16.7	24635
6	Jacarehy	.56	23 18 10	45 57 32	8 07.5W	14 27.2	24573
7	Mogy das Cruzes	.59	23 31 25	46 11 39	7 52.8W	14 43.4	24618
8	S. Paulo	.62	23 32 42	46 34 32	7 31.1W	14 32.6	24652
9	S. Roque	.65	23 31 46	47 08 20	7 02.3W	14 22.9	24734
10	*Sorocaba*	.66	23 29 23	47 27 51	6 48.3W	14 13.6	24606
11	Tieté	.77	23 06 55	47 42 50	7 17.9W	14 34.3	24478
12	Botucatú	.82	22 52 39	48 26 16	5 54.6W	13 41.0	24868
13	Baurú	.85	22 19 40	49 04 09	5 57.5W	12 34.6	25059
14	Presidente Penna	.87	21 47 46	49 36 08	5 41.4W	11 24.1	25247
15	Miguel Calmon	.90	21 27 41	49 56 09	4 54.1W	10 48.3	25255
16	Araçatuba	.91	21 12 11	50 25 45	4 53.9W	10 18.8	25449
17	Itapura	.92	20 39 24	51 30 36	4 20.9W	9 07.5	25562
18	Tres-Lagôas	.93	20 47 21	51 42 04	3 58.3W	9 06.2	25501
19	Itapetininga	1914.08	23 35 25	48 02 45	6 16.0W	14 24.2	24728
20	Faxina	.08	23 57 55	48 52 45	5 41.1W	14 21.0	24554
21	Itararé	.11	24 06 31	49 19 58	5 05.0W	14 15.8	24694
22	Pirahy	.14	24 31 40	49 56 46	3 55.5W	15 47.8	24620
23	*Ponta Grossa*	.19	25 05 57	50 09 33	4 04.6W	16 10.7	24547
24	Iraty	.25	25 27 56	50 37 51	3 41.8W	15 58.5	24633
25	Porto União da Victoria	.25	26 13 54	51 04 32	2 37.4W	17 39.6	24353
26	*Herval*	.26	27 10 19	51 29 48	0 05.2W	18 53.8	25398
27	Marcelino Ramos	.27	27 27 40	51 54 22	1 09.3W	19 41.1	25087
28	*Passo-Fundo*	.31	28 15 39	52 24 33	1 36.9W	20 28.8	24423
29	*Cruz-Alta*	33	28 38 21	53 36 34	0 30.9W	19 58.8	24402
30	*Sta. Maria da B. do Monte*	.39	29 41 25	53 48 42	0 04.9W	21 33.4	24737
31	Cacequy	.37	29 52 56	54 49 32	1 02.1 E	21 50.6	24574
32	*Alegrete*	.40	29 46 45	55 47 27	6 40.9 E	23 07.2	23755
33	*Uruguayana*	.42	29 45 11	57 04 52	2 11.6 E	19 19.6	24673
					2 06.4 E	23 14 1	24279
34	*Barra do Quarahim*	.45	30 12 37	57 33 00	4 11.5 E	22 27.9	24993
35	*Itaquy*	.48	29 07 54	56 33 20	2 44.5 E	21 37.5	24802
36	*S. Borja*	.50	28 39 33	55 59 42	1 45.3 E	20 16.7	24794
37	*S. Gabriel*	.53	30 20 06	54 18 48	0 44.7 E	22 30.6	24518
38	*Bagé*	.58	31 19 59	54 07 02	0 46.8 E	23 52.4	24465
39	*Pelotas*	.60	31 45 44	52 21 04	0 38.9W	24 21.0	24184
40	*Porto Alegre*	.64	30 04 12	51 08 18	2 10.6W	22 39.3	24243
41	Rio Pardo	.67	29 58 52	52 22 27	1 09.4W	21 58.5	24341
42	*Cachoeira*	.71	30 02 45	52 53 39	0 42.5W	22 23.0	24396
43	*Jundiahy*	.83	23 11 39	46 52 33	7 26.0W	14 04.6	24555
44	Mogy-Guassú	.91	22 22 18	46 57 08	7 30.1W	12 31.6	25000
45	Casa-Branca	.90	21 46 40	47 05 34	7 10.6W	11 26.2	25028
46	*Ribeirão Preto*	.92	21 10 40	47 48 24	7 15.7W	11 38.2	25024
47	*Franca*	.98	20 32 29	47 24 24	7 23.2W	11 37.2	25084
48	*Rifaina*	1915.02	20 04 44	47 25 30	7 39.6W	9 25.6	25436
49	*Uberaba*	.03	19 44 36	47 56 16	7 01.4W	8 57.2	25456
50	*Araguary*	.05	18 38 30	48 11 18	7 02.4W	6 56.9	25726
51	Ouro-Fino	.07	22 16 31	46 22 32	8 19.2W	12 50.0	25129
52	Pouso-Alegre	.08	22 13 36	45 56 34	8 42.0W	13 10.2	25202
53	Itajubá	.10	22 25 30	45 28 03	8 49.4W	14 02.3	24534
54	Caxambú	.11	21 58 39	44 56 15	9 26.0W	13 22.1	24828
55	Passa-Quatro	.12	22 23 26	44 58 12	9 36.0W	13 54.2	24618
56	*Vassouras*	.19	22 24 01	43 39 04	10 24.4W	14 38.2	24652

[1] These results were communicated to the Journal by Dr. H. Morize, Director of Observatoire National de Rio de Janeiro. The work was executed by Herminio Fernandes da Silva (Cf. *Terr Mag.*, vol. 21, 1916, pp. 23-24.)

[2] At the stations italicised, the longitudes were determined telegraphically.

DESCRIPTIONS OF STATIONS.

1. Geographic position is that determined by Mr. Pereira Reis. Magnetic observations were made on little hill, left bank of the Parahyba River, exactly opposite its confluence with the Pirahy River.
2. Position refers to Senhor dos Passos Church. Magnetic observations were made on hill called "Alto dos Passos."
3. Position, determined by Mr. Lacaille, refers to principal church, "Matriz." Magnetic observations were made on public place in front of cemetery.
4. Position, determined by Mr. Lacaille, refers to principal church, "Matriz." Magnetic observations were made in "Campo da Olaria Marcondes."
5. Position refers to the Santa Clara Convent, in the inclosure beside which the magnetic observations were made.
6. Praça Marechal Floriano.
7. Praça Campo Santo.
8. Located in outskirts of town, at Central Railway station, "Quinta Parada."
9. Praça da Republica.
10. Field to left of cemetery and adjacent to it.
11. Field called "Campo do Matto," in the suburb "Barra Funda."
12. Field at end of Riachuelo street.
13. Position refers to Misericordia Hospital, in front of which the magnetic observations were made.
14. Position refers to railway station behind which the magnetic observations were made at a point 180 m. from the line.
15. Position refers to Santa Luzia Church, by the side of which the magnetic observations were made.
16. Position of railway station, in front of which the magnetic observations were made, 160 m. from the line.
17. Position of railway station, in front of which the magnetic observations were made, 80 m. from the line.
18. Position of barracks before which the magnetic observations were made.
19. Praça Rosario.
20. Position of railway station. Magnetic observations were made in the "campo" beside the "Escola da Estação."
21. Praça S. Pedro.
22. Praça Andrade Pinto.
23. At crossing of streets, "Sete Setembro" and "Municipal."
24. Position of railway station. Magnetic observations were made on the "Campo da Fabrica Peixoto."
25. Position of schoolhouse. Magnetic observations were made on the Praça Vicente Machado.
26. Position of railway station. Magnetic observations were made in different places, of which one was behind the station, 80 m. from the line.
27. Position of railway station. Magnetic observations were made in the field beside the Pereira Hotel.
28. At intersection of streets, "General Ozorio" and "Da Fabrica."
29. "Campo" in which "Pilar" street ends.
30. Praça da Republica.
31. Position of railway station. Magnetic observations were made on road leading to "S. Vicente," 200 m. distant from the line.

32. Praça Club Emancipado. The magnetic observations show anomalies.
33. Position corresponds to that of the Praça Geral Ozorio. As very marked anomalies were noted, the magnetic observations were made in several places.
34. "Campo," distant 210 m. from the railroad, behind the station, to which the position refers.
35. Position of railway station, in front of which the magnetic observations were made, 205 m. from the line.
36. Praça 13 de Maio.
37. Praça S. Luiz.
38. Highest part of Praça da Republica.
39. Farm belonging to tramway company.
40. Position of Agronomic Institute, in front of which the magnetic observations were made.
41. Position of old military school, beside which the magnetic observations were made.
42. "Chacara Virgilio de Abreu," at the end of Andrade Neves Street.
43. Position of railway station. Magnetic observations were made between the "Gaipeva" River and "Vigario Ruiz" and "Dr. Calvacanti" avenues.
44. Farm or "chacara" of Colonel João Franco Bueno, "15 de Novembro" street.
45. Place without a name, between S. Antonio, Aurora and Paysandú streets.
46. Place between Garibaldi, Commercio and Duque de Caxias streets.
47. "Campo" beside the cemetery.
48. Position of the Sto. Antonio Church, before which the magnetic observations were made.
49. Observations were made on hill "do Fabricio." The magnetic values found show anomalies attributable to the nature of the soil.
50. Position of S. João Church, in front of which the magnetic observations were made.
51. Position of railway station, in front of which the magnetic observations were made.
52. "Chacara" of Colonel Joaquim Augusto, between Adolpho Olyntho and da Cruz streets.
53. "Campo" at the end of "Rua Nova," on the bank of the Sapucahy River.
54. Caxambú Hill. Observations were made on the road, opposite extension of João Pinheiro street.
55. Position of railway station. Magnetic observations were made on hill situated behind station.
56. Vassouras Magnetic Observatory.

LETTERS TO EDITOR

THE MAGNETIC CHARACTER OF THE YEAR 1915.

The annual review of the "Caractère magnétique de chaque jour" for 1915 has been drawn up in the same manner as the preceding years. Thirty-eight observatories contributed to the quarterly reviews; 35 of them sent complete data. Table II of the annual review, containing the mean character of each day and each month, the list of "calm days" and the days recommended for reproduction are reprinted here.

De Bilt, Aug. 4, 1916. G. VAN DIJK.

Table Showing the Magnetic Character of the Year 1915.

Dates	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Mean
January	1.3	0.0	0.1	0.6	1.5	0.8	0.8	0.7	0.3	0.1	0.1	0.8	0.8	0.8	0.3	0.1	0.3	0.0	0.0	0.6	0.3	0.4	0.1	0.5	1.4	1.1	0.9	0.7	0.4	0.6	0.1	0.53
February	0.6	0.7	0.1	0.4	0.9	0.5	0.1	1.3	1.1	0.4	0.1	0.6	0.3	0.0	0.4	0.0	0.2	0.1	1.5	1.3	1.1	1.1	1.3	1.2	1.0	1.0	0.4	0.3				0.64
March	0.1	0.1	0.1	0.2	0.4	0.7	1.2	1.4	1.1	0.7	0.6	0.5	0.3	0.1	0.1	0.7	0.9	0.9	0.9	1.5	1.6	1.5	1.0	0.7	1.1	0.8	0.3	0.2	0.4	0.8	0.2	0.68
April	0.5	1.1	0.9	0.3	0.2	0.4	1.1	1.5	0.4	0.1	0.2	0.1	0.0	0.3	1.1	1.0	0.5	1.0	1.0	0.9	0.8	1.3	1.0	0.1	0.2	1.3	0.3	0.1	0.1	0.5		0.61
May	1.2	1.3	0.9	0.8	0.5	0.1	0.0	0.0	0.3	0.1	0.1	0.7	0.6	0.7	0.7	1.1	1.3	0.2	0.8	0.9	0.9	0.7	0.3	0.6	0.6	0.3	1.3	0.0	0.0	0.5	0.6	0.58
June	0.1	0.1	0.0	0.0	0.0	0.1	0.6	0.9	0.5	0.1	0.5	1.4	1.4	0.9	0.2	0.9	2.0	1.7	0.1	0.2	1.0	1.2	0.7	0.4	0.9	0.7	0.6	0.4	0.7	0.1		0.61
July	0.3	1.2	0.7	0.0	0.2	1.1	0.0	0.7	1.1	0.9	1.1	1.0	0.2	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.8	0.3	0.1	0.6	0.8	1.2	0.2	0.9	0.7	0.1	0.47
August	0.8	1.2	1.0	0.7	0.0	0.8	1.2	0.8	0.1	0.8	0.2	0.1	0.0	0.0	0.0	0.2	0.9	0.6	0.9	0.5	0.7	0.4	0.3	0.1	0.8	1.6	1.0	0.9	1.2	0.8		0.60
September	0.0	0.1	0.1	0.0	0.5	0.1	0.1	0.0	0.1	0.6	0.2	0.3	0.7	0.1	0.2	0.9	1.1	0.1	0.1	0.0	0.4	1.6	1.8	1.3	1.1	1.2	1.1	1.3	1.3	1.2	0.3	0.59
October	0.7	0.1	0.3	0.2	0.0	0.1	0.4	0.1	0.0	1.1	0.7	0.1	0.1	1.5	1.9	1.4	0.9	0.2	1.6	1.4	1.2	1.2	1.9	1.5	1.6	1.1	0.5	0.3	0.3	0.7	0.8	0.77
November	1.6	0.8	0.3	0.2	1.6	2.0	0.9	0.9	0.5	0.9	0.8	0.9	0.3	0.0	1.2	1.7	1.5	1.5	1.1	1.1	1.0	1.0	0.3	0.1	0.3	0.6	0.9	0.9	0.0	0.1		0.82
December	0.0	0.1	0.3	0.1	0.1	1.9	1.1	0.5	0.6	0.5	0.8	0.7	0.0	0.9	1.4	0.9	0.4	0.1	0.3	0.3	0.0	0.1	0.9	0.6	0.9	1.1	0.9	0.2	0.3	0.3	0.3	0.54

Calm Days.

January	2,	3,	18,	19,	31.	February	7,	11,	14,	16,	17.	March	2,	3,	14,	15,	28.
April	10,	11,	12,	13,	28.	May	7,	8,	11,	28,	29.	June	3,	4,	10,	20,	30.
July	4,	15,	16,	17,	24.	August	5,	13,	14,	15,	24.	September	7,	8,	18,	19,	20.
October	2,	5,	9,	18,	29.	November	3,	4,	14,	29,	30.	December	1,	5,	18,	21,	22.

Days Recommended for Reproduction.

** March 21, April 8, June 17, November 6, December 6.
* January 25, February 19, April 26, August 26, September 22, 23, October 15, October 23.

THE EFFECT OF LUNAR DISTANCE ON THE MAGNETIC DECLINATION AT ZI-KA-WEI.

The March 1916 issue of the Journal, pages 25-26, contains an interesting letter by Father de Moidrey, S. J., on the "lunar-diurnal variation of the magnetic declination at Zi-Ka-Wei." The fact which he has brought to light proves, on examination, to be somewhat remarkable and unexpected. It relates to the solar-diurnal[1] amplitude of declination, defined as the difference between the elongations normally occurring towards sunrise and at mid-day (occasional maxima or minima at other times, due to disturbances, are neglected). The values P, A of this diurnal amplitude at the times of lunar perigee and apogee, respectively, were determined from three cycles of 10 or 11 years each. Periods of five days centered at apogee or perigee were taken in two of these cycles, and three days in the third. The following values of P/A were obtained:

1.010, 1.029, 1.023   Mean = 1.023 ± 0.01; probable error, ± 0.04

This evidence for a larger diurnal amplitude at perigee than at apogee must be accorded considerable weight.

Father de Moidrey remarks that "these numbers are slightly smaller than those obtained by Dr. Chapman," referring to a recent paper (*Phil. Trans.* A, 215, pp. 161-176, 1915) in which it was shown that the lunar-semidiurnal magnetic variation is larger at perigee than at apogee. The ratio (P'/A', say) of the latter variation, determined from periods of three or four days about those epochs, was found to be approximately 1.39. The effects disclosed by P'/A' and P/A are consequently of totally different orders of magnitude: but this is not surprising, since they relate to very different phenomena. The lunar-diurnal variation of magnetism appears to result from an atmospheric tide produced by the Moon, and the value 1.39 for P'/A' tends to corroborate this hypothesis, since 1.39 is the ratio of the tide-producing force of the Moon at perigee and apogee. The change from A' to P' takes place quite independently of the solar-hour angle.

The ratio P/A, on the contrary, relates to a magnetic variation depending primarily on solar time. It is natural to examine whether the difference between P and A is due to the superposition of the lunar-diurnal variation, which we know depends largely on the Moon's distance, upon a *constant* solar-diurnal variation. We will confine our attention to the lunar-semidiurnal term, which is much the most important part of the lunar variation; its total amplitude at Zi-Ka-Wei (over the mean of a year) I have found to be approximately $0'.43$.[2] The *change* in this between apogee and perigee (i. e. 39%) is consequently $0'.16$. Since the declination ranges over its solar-diurnal amplitude ($5'.5$ in the mean of a year) within about six hours, sunrise to mid-day, and since this is nearly one quarter of a lunar day, if the phase of

[1] *Not* lunar-diurnal, as the title of the letter would indicate.

[2] More detailed data concerning the lunar-magnetic variation at Z.-Ka.-Wei and other observatories will be found in a paper which I hope shortly to publish.

the lunar-semidiurnal variation were favourable and constant, the whole of its perigee-apogee variation might appear in the "diurnal amplitude." In this case we should have

$$\frac{P}{A}=\frac{5'.50+\frac{1}{2}(0'.16)}{5'.50-\frac{1}{2}(0'.16)}=\frac{5.58}{5.42}=1.029$$

which agrees fairly well with the value actually found.

Unfortunately this interpretation of de Moidrey's result must be rejected, simply because the phase of the lunar-semidiurnal variation at apogee or perigee is continually changing, relative to solar time, on account of the difference between the synodical and anomalistic months. If therefore at one time the increased amplitude of the lunar variation at apogee is contributing to the observed excess of P over A, at another time it will be acting in the opposite direction. In the course of ten years this effect on P and A should average out completely.

The effect of lunar distance indicated by P/A would therefore appear to be brought about in some other way; its amount is too small to be referred to a direct tidal action, though it may arise differentially from this or some other direct influence. The difficulty in the way of a resolution of the problem only increases its interest, however, as possibly containing a clue to some unsuspected lunar action. For the same reason further investigation and corroboration of the result are to be desired. S. CHAPMAN.

Royal Observatory, Greenwich,
June 24, 1916.

NOTES

13. *Personalia.* We regret to record the following deaths: on May 17, the eminent geophysicist, *Prince B. B. Galitzine;* on June 18, *Robert H. Scott,* F. R. S., superintendent of the Meteorological Office from 1867 to 1900; on June 12, *Silvanus P. Thompson,* well known for his contributions to physical science and to terrestrial magnetism as well—witness, for example, the amount of time, labor and love bestowed on the translations of "De Magnete" (with accompanying Notes), the epistle of Peter Peregrinus written in 1269, etc.; on September 12, at 80 years of age, *H. Mohn,* the well-known meteorologist and magnetician.

Th. Hesselberg was appointed Director of the Meteorological Institute of Norway from January 1, 1916.

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME XXI DECEMBER, 1916 NUMBER 4

PRELIMINARY REPORT ON THE RESULTS OF THE AURORA-BOREALIS EXPEDITION TO BOSSEKOP IN THE SPRING OF 1913. (FIFTH COMMUNICATION.)

BY CARL STÖRMER, *Kristiania*.

1. In this Journal for September, 1913, March and December, 1915, and June, 1916, I published preliminary reports on my aurora-borealis expedition of the spring of 1913. The present communication relates to the material of the last two nights, March 30 and April 1, 1913, comprising about 90 auroral photograms.

Fig. 1 shows the distribution of calculated altitudes of auroras above the surface of the Earth. These altitudes are not as concentrated around the 100 km. level as in the corresponding cases of March 14-15 and 16 to 29, mainly owing to the fact that the auroras of April 1-2 were all very faint and relatively tranquil.

2. I shall now consider some of the photograms taken during the night of March 30 and 31. In accordance with the method previously adopted, the aurora seen from Bossekop was drawn, and a series of points were chosen along its edges and rays; each point was then connected by means of a dotted line with the corresponding position of the same point seen from the other station. The length of this line measured in degrees then gives us the parallax. The computation gave the following altitudes in km.:

No..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Alt..	120	121	111	108	112	117	122	125	124	123	117	115	127	129	115	113	109

The relatively high position of this aurora is in harmony with its faintness, as compared with the curtains descending to 90-100 km.

The next 4 photograms exhibit the above-mentioned intense development of auroral displays between 10^h 40^m and 10^h 50^m. The first, taken at 10^h 45^m, shows a very pronounced arc near the star Capella. The altitudes in this case are as follows in kilometers:

Number...........	1	2	3	4	5	6	7
Altitude...........	109	107	106	108	104	105	105

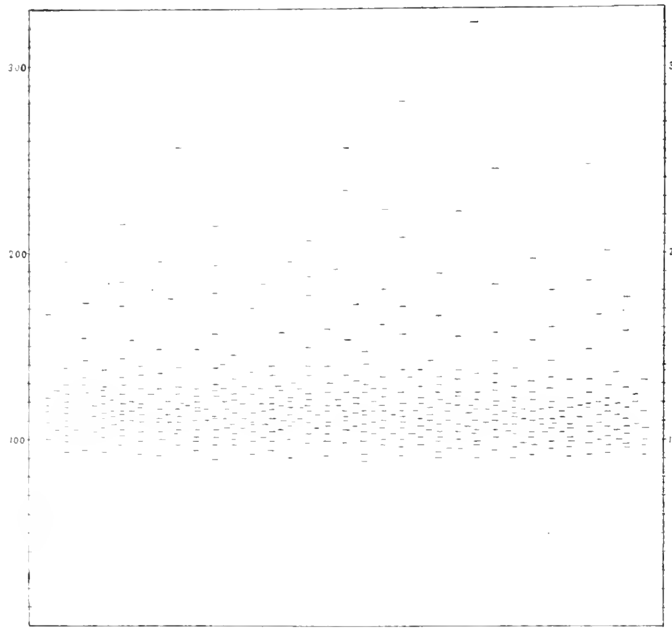


FIG. 1.

During the succeeding minutes the arc developed into some of the most splendid curtains that I have ever seen. The intensity was extremely great, and the aurora radiated in various colors, particularly green, white, and red. The altitudes in km. are:

Number	1	2	3	4	5	6	7	8
Altitude	116	94	93	91	89	97	92	97

As will be observed, the curtain penetrated down to the lower limit of altitude for the auroras observed on our expedition of 1913. Plate XI shows the aspect of the curtain at 10 h 46 m 22 s, exposure 2 sec. Only the lowermost luminous part of the curtain has acted on the photographic plate (Ultra rapid, Hauff, Feuerbach).

The extension in a vertical direction of the most luminous part of the auroral curtain is of fundamental importance in the question of the absorption of the auroral corpuscles in the Earth's atmosphere.[1] A first computation of this vertical thickness in km. gave:

Near point number	3	5	7
Thickness	27	19	28

At $10^h\,46^m\,37^s$, another photogram (Plate XII) was taken, with an exposure of 2 sec. During the exposure the camera at Bossekop was slightly moved, thus producing double stars; however, the

[1] See P. LENARD: Über die Absorption der Nordlichtsstrahlen in der Erdatmosphäre, Sitzungsberichte der Heidelberger Akademie der Wissenschaften, 1911, and also my Geneva paper: Sur les trajectoires des corpuscles électrisés dans l'espace etc., Archives des Sciences physiques et naturelles, T. XXXII.

Photographed from Bossekop.

Photographed from Store Korsnes.

AURORA, MARCH 30, 10^h 46^m 22^s, 1913.

Photographed from Bossekop. Photographed from Store Korsnes.

AURORA, MARCH 30, $10^h\ 46^m\ 37^s$, 1913.

movement was so slight that no appreciable effect was produced in the parallax. The altitudes of the points here are in kilometers:

Number	1	2	3	4	5
Altitude	99	99	98	97	95

The vertical thicknesses of the curtain's most luminous part are:

Near point number	2	3	4	5
Thickness	27	28	29	24

I may return later to the consequences of these computations.

For a later stage of the development of the aurora, at $10^h 48^m 12^s$, 3 seconds exposure, the following altitudes in km. result:

Number	1	2	3	4	5
Altitude	99	110	111	102	92

3. I shall mention finally some interesting photograms of the night of April 1-2. During that night the auroras were very faint and tranquil, very different from those, for instance, that occurred on March 14-15. Along the right border of the ray a series of points were chosen, the following altitudes in kilometers being obtained:

Number	1	2	3	4	5
Altitude	245	222	191	170	153

The corpuscular rays producing the auroral ray had consequently very slight penetrating power, and are probably essentially different from those descending to about 90 kilometers above the ground. As stated before, the aurora on the night in question was very faint and tranquil. For a long period there were only some very faint arcs over the northern sky, and no aurora was visible elsewhere. A photogram of two arcs of this kind, taken at $12^h 05^m$, is seen in the plate published in the *Astrophysical Journal*, November, 1913, vol. 38, p. 311. These arcs were so faint that it was just possible to see them, and in consequence the exposure was a very long one—1 minute. The constellation Perseus appeared in the background. I was very curious to see whether these areas lay very high in the air, but on computation it was found that the altitude was not at all unusual. The points selected gave the altitudes in km.:

Number	1	2	3	4	5	6
Altitude	104	101	94	90	92	92

Because the arcs are very faint and diffuse, the determination of their altitudes and positions is probably somewhat uncertain.

On April 1-2 the display was terminated by a curtain far away in the northwest, lasting from $12^h 43^m$ until $12^h 46^m$. Six successive photograms were taken. The altitudes in km. are:

Number	1	2	3	4	5	6
Altitude	131	110	117	116	117	114

Along the lower edge was a small luminous border with vertical thickness in km., according to a preliminary computation, as follows:

Near point number	3	4	5	6
Thickness	12	12	11	12

This thickness is much less than that for the previous cases.

The next photogram was taken at $12^h\ 44^m$, and another at $12^h\ 44^m\ 37^s$. We have shown in the latter a very characteristic auroral curtain, frequently observed, especially on days of faint and tranquil auroral display. The curtain is folded, and the left portion has its light augmented because we are looking at the curtain tangentially; the altitudes in kilometers are:

Number...	1	2	3	4	5	6	7	8	9	10
Altitude...	161	140	119	109	108	128	104	103	112	120

The vertical thicknesses in kilometers of the most luminous part near the lower border of the curtain are:

Near point number......	7	8	9
Thickness..............	14	13	14

The next photogram, at $12^h\ 45^m\ 04^s$, was taken more to the north, with Capella in the background. The altitudes in km. are here:

Number.......	1	2	3	4	5
Altitude.......	124	120	111	114	112

The vertical thicknesses in km. of the most luminous part are:

Near point number........	2	3	4	5
Thickness.................	10	10	11	10

Two more photograms of the same aurora were taken, namely at $12^h\ 45^m\ 22^s$ and $12^h\ 45^m\ 54^s$. They gave positions marked on the chart in Fig. 2 as V and VI. For purposes of comparison, two circles with radii of 21° and 22°, respectively, and with their centers on the magnetic axis of the Earth, are drawn on the chart. They represent, as is well known, magnetic parallels, if we drop all the terms, except the first, from the spherical-harmonic series representing the Earth's magnetic potential in space. The relative positions of the auroral curtains with respect to these circles are of theoretical importance, as mentioned in former reports. I shall return to this question in the discussion of the whole material.

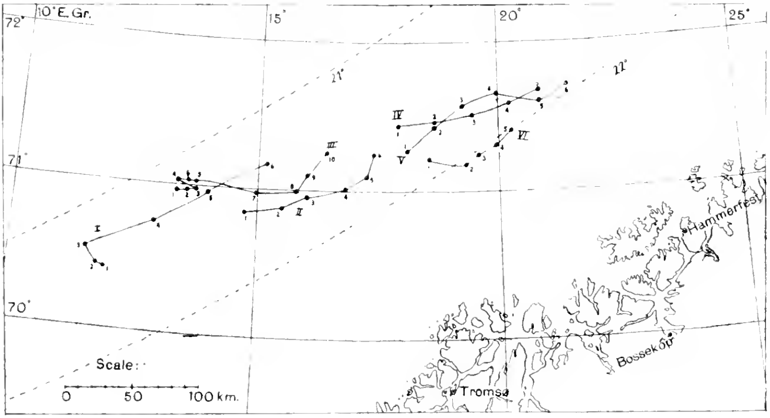


FIG. 2.

SUMMARY OF RESULTS OF THE AURORA-BOREALIS EXPEDITION OF 1913 TO BOSSEKOP, NORWAY.

By Carl Störmer, *Kristiania*.

In this Journal I have published preliminary reports on the results of the Aurora-Borealis Expedition undertaken by me in the spring of 1913 to Bossekop, in the northern part of Norway. I now propose to give a summary of the chief results.

Altitude and Situation of Auroras.

With respect to the altitude and situation of the auroras observed during the expedition, diagrams were given in the foregoing reports. Fig. 1 shows all the altitudes observed. We have here about 2,500 single points, each one representing the altitude of a chosen point of the aurora. Revised calculations of the number of points for each altitude are given in Table 1.

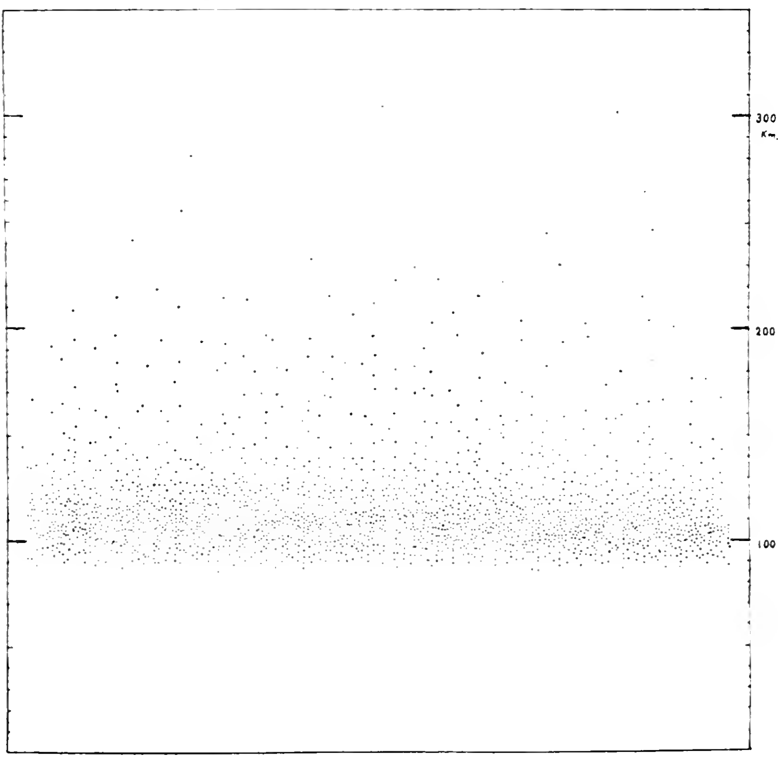


Fig. 1.

FIG. 1.—*Number of Points for Altitudes, 86-226 Km.*

Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.
86	0	107	94	127	24	147	9	167	2	187	3	207	0
87	3	108	90	128	24	148	8	168	1	188	2	208	1
88	7	109	75	129	19	149	7	169	3	189	0	209	1
89	11	110	76	130	16	150	0	170	2	190	0	210	1
90	23	111	69	131	10	151	2	171	3	191	2	211	0
91	23	112	69	132	17	152	5	172	3	192	1	212	1
92	27	113	69	133	12	153	3	173	1	193	1	213	0
93	28	114	55	134	16	154	2	174	2	194	3	214	1
94	37	115	65	135	11	155	4	175	1	195	5	215	3
95	35	116	39	136	8	156	4	176	1	196	0	216	0
96	42	117	48	137	16	157	4	177	4	197	5	217	0
97	44	118	51	138	10	158	3	178	1	198	0	218	0
98	42	119	39	139	17	159	6	179	0	199	0	219	1
99	69	120	52	140	7	160	5	180	4	200	0	220	0
100	74	121	26	141	8	161	3	181	2	201	1	221	0
101	77	122	40	142	9	162	4	182	1	202	1	222	1
102	77	123	25	143	7	163	0	183	3	203	2	223	1
103	90	124	29	144	3	164	4	184	2	204	1	224	0
104	76	125	33	145	4	165	2	185	2	205	1	225	0
105	105	126	28	146	9	166	4	186	0	206	1	226	0
106	99												

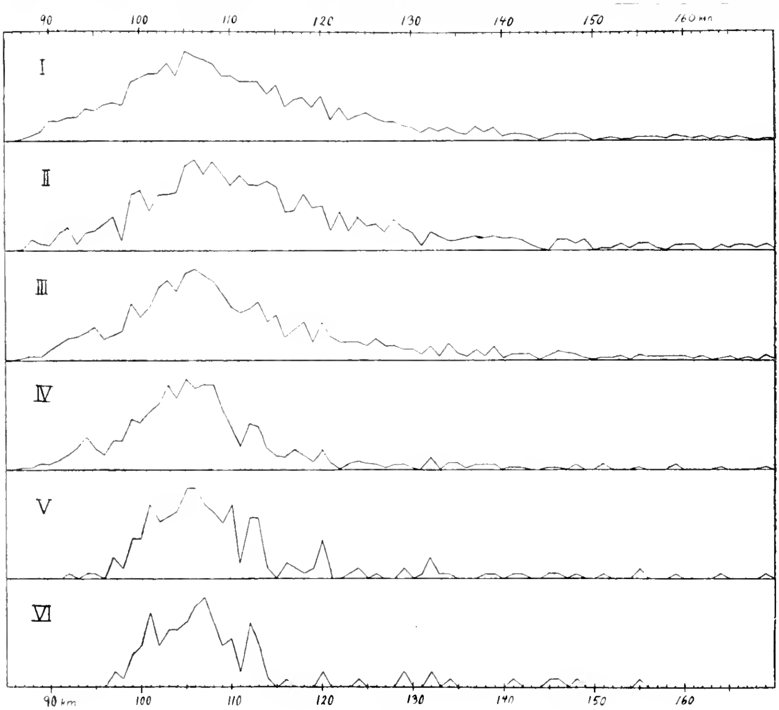


FIG. 2.

For altitudes over 226 km., Table 2 contains those which gave numbers differing from zero. The tabulated quantities have been controlled in five other ways, the results of which are reproduced in Fig. 2, showing curves in which the altitudes are chosen as abscissæ and the number of points as ordinates. The scales are selected in such a manner that the maximum of each curve has the same value. In curve I, for the purpose of comparison, the results given in Table 1 are reproduced.

TABLE 2.—*Number of Points for Altitudes, 229-323 Km.*

Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.
229	1	233	1	245	1	256	2	281	1	319	1
232	1	242	2	247	1	265	1	282	1	323	1

In curve II, all points were dropped which on the drawings of the negatives lay outside a circle having a radius of 10°, and its center in the middle of the line joining the two points toward which the optical axis of the photographic lenses at Bossekop and Korsnes were directed. Thus only the points near the center of the images are taken into account.

In curve III, only the points were counted satisfying the conditions (see Fig. 3):

$$p = 4^\circ \qquad 60^\circ = u + p = 120^\circ$$

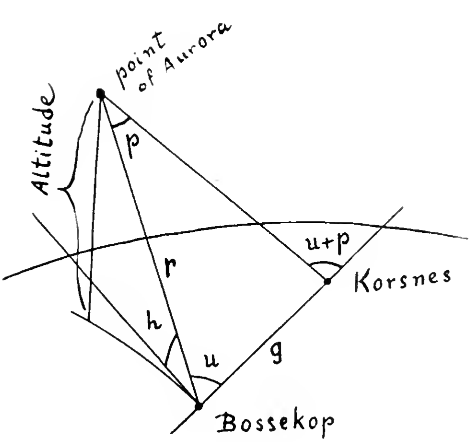


FIG. 3.

As is well known, the distance r from Bossekop to the aurora-point in question is given by the formula[1]

$$r = \frac{g \sin (u + p)}{\sin p}$$

where the meaning of the letters are indicated in Fig. 3.

In curve IV, Fig. 3, only the points where

$$p \geqq 8°, \text{ and } 60° \leqq u + p \leqq 120°$$

were taken into account. In this manner the points giving small parallaxes or lying near the line joining the two stations were discarded.

For curve V, only the points the distance of which from the zenith at Bossekop did not exceed 30° were chosen; i. e., those corresponding to the condition:

$$h \geqq 60°.$$

In the same manner, in curve VI, only those points where

$$h \geqq 70°$$

were chosen.

From these curves we appear to be justified in drawing the following conclusions: *There are two predominant maxima, one about* 101–103 *km., and the other about* 105–108 *km. Secondary maxima are found near the levels* 94 *km.,* 112 *km.,* 120 *km., and* 132 *km.* The first two maxima were seen already on the diagram of altitudes for March 14 and 15[2]; the revised numbers for these two days are:

Altitude.....	98	99	100	101	102	103	104	105	106	107	108	109
Number.....	17	26	28	35	23	30	21	47	44	41	34	22

As already remarked in the second communication,[3] the lower limit of 87 km. for the 1913 auroras is astonishingly high. Since 1913 was a very marked minimum year for the frequency of solar activity, aurora, and magnetic storms, it is probable that this very high lower limit was due to the small penetrating power of the electric corpuscles, which, emanating from the Sun, were stopped in the outer parts of our atmosphere. From previous altitude-measurements it seems as if the lower limit of the aurora displays is much lower during years of maximum frequency. Definite knowledge on this point would mark a very important advance.

[1] For details, see my paper: "Bericht über eine Expedition nach Bossekop," etc., *Videnskabsselskabets Skrifter*, 1911, No. 17, Kristiania.

[2] See *Terr. Mag.*, v. 20, p. 151. [3] *Terr. Mag.*, v. 20, pp. 1-12.

As regards the geographical distribution of the points on the Earth's surface which have the calculated aurora-points in the zenith, the result for 2,500 points is shown in Fig. 4. They lie mainly to the west, north, and east of Bossekop. During years of maximum frequency of aurora, the displays are seen much more to the south of Bossekop. Thus, for instance, the director of the Hallde Observatory (13 km. from Bossekop), Mr. Krogness, has informed me that such is the case at present.

Fig. 4 shows, also, circles with their centers on the Earth's magnetic axis and their plane normal to that axis. The angle between the magnetic axis and the line joining the center of the Earth and the periphery of the circle is given on each circle. See also the foregoing communications.

After this general review regarding the altitude and distribution of the aurora, let us next examine more closely the details, for the purpose of determining on special types of aurora with characteristic physical properties.

Special Types of Auroras.

Type A.—*Very intense, vari-colored aurora-curtains, mostly red underneath and greenish-yellow in the upper parts; time of exposure not exceeding 4 sec.; on an average, 2 sec.* Aurora displays like these were shown by the photographs of March 30 at 10^h 46^m, reproduced in the fifth communication, plates XI and XII. The altitudes of 19 auroras of this type are seen in Fig. 6 (p. 165); only points along the lower edge of the curtain were measured, and the lowest point for each aurora is marked by a line, the other points by dots.

It should be remembered that the different parts of the lower edge of an aurora-curtain may have very different altitudes.[1] The distribution of altitudes is shown in Table 3.

Table 3.—*Distribution of Altitudes for Type A.*

Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.
88	1	94	2	100	3	106	1	112	2	118	2	124	1
89	2	95	2	101	1	107	2	113	0	119	1	125	0
90	3	96	4	102	1	108	4	114	1	120	0	126	0
91	5	97	4	103	3	109	0	115	1	121	0	127	1
92	4	98	5	104	1	110	1	116	1	122	0		
93	5	99	3	105	4	111	2	117	4	123	0		

The geographical position of the auroras of Type A is shown in Fig. 5. Points belonging to the same curtain are connected by lines.

[1] See, for instance, *Terr. Mag.*, v. 20, p. 8, lower table of altitudes.

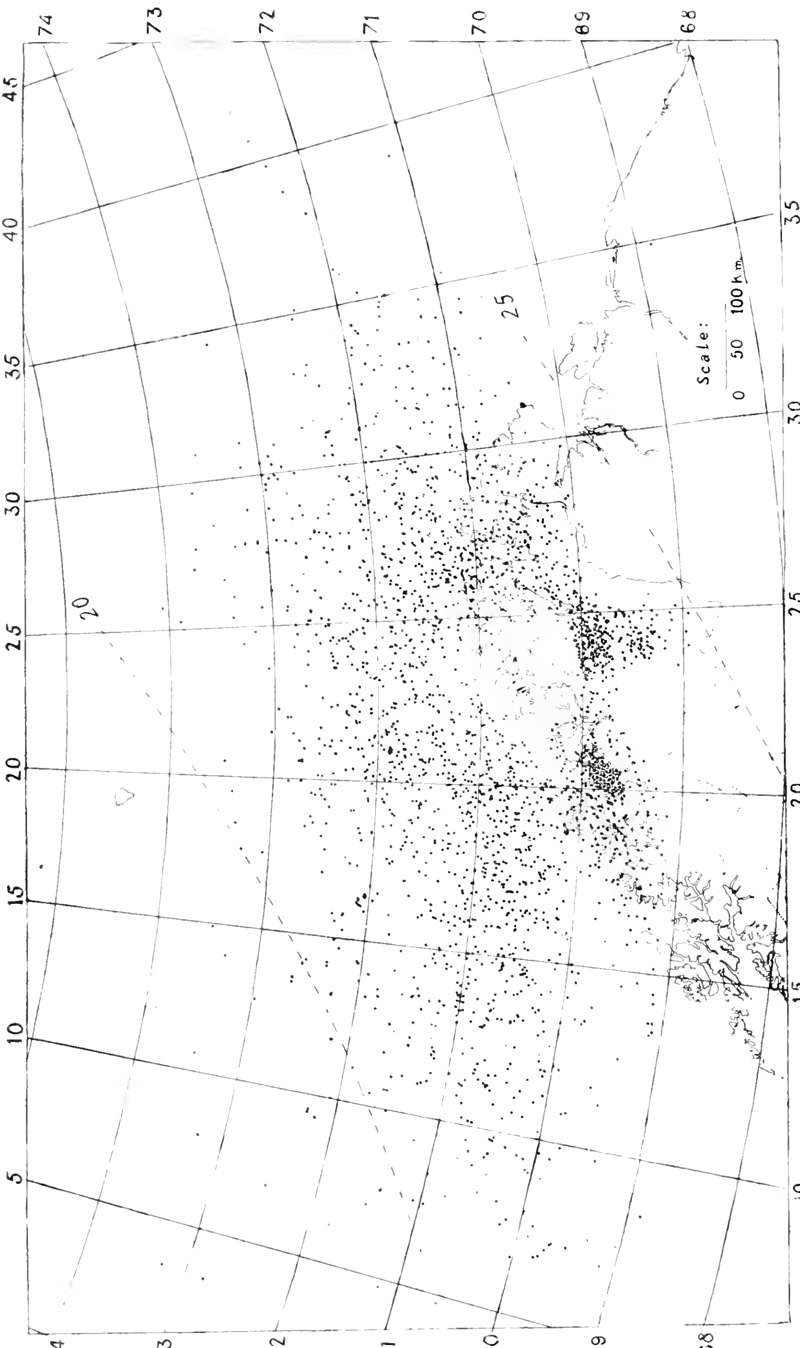


FIG. 4.

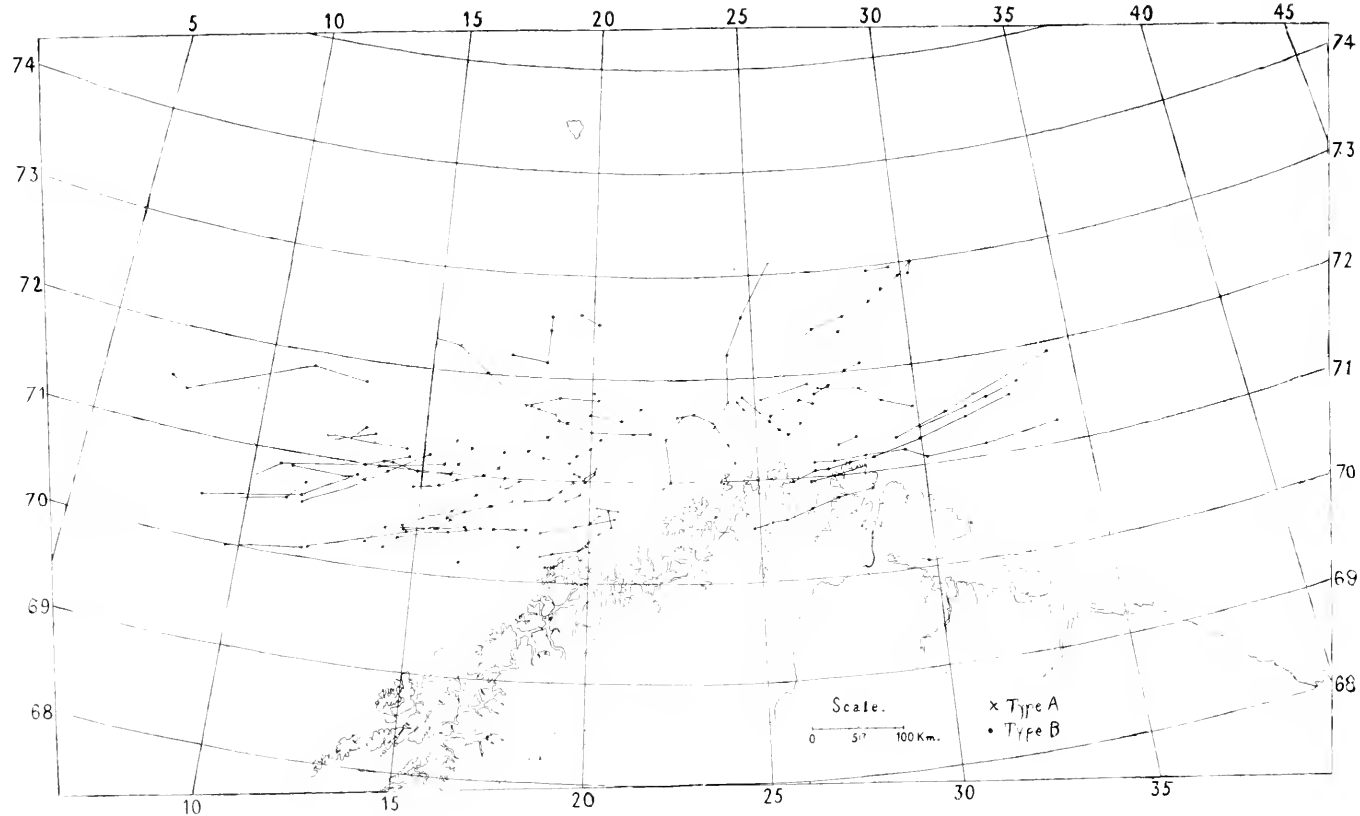


FIG. 5.

Type B.—*Faint and tranquil aurora-curtains, color uniformly greenish to greenish gray; time of exposure from 5 to 20 sec., on an average, 11 sec.* Aurora curtains of this kind are shown on a picture published in the Bulletin de la Société Astronomique de France, November, 1913, from a photograph taken on March 3, 1913, at $10^{h}\ 16^{m}$. Other cases were shown by the photographs of the aurora-curtains of March 30, at $10^{h}\ 20^{m}$, and April 1, at $12^{h}\ 43^{m}$ to $12^{h}\ 46^{m}$. The altitudes of 32 auroras of Type B are shown in Fig. 7. Only the points along the lower edge were measured, and the meaning of points and lines is the same as that in Fig. 6, page 165.

Many of the aurora-curtains of this kind were situated far off in the northwest. The parallaxes are therefore mostly small (about 3°), which causes some uncertainty in the computation of the altitude. But the auroras mentioned above, especially that of March 30, at $10^{h}\ 20^{m}$, the altitude of which was given in the fifth communication, are relatively well measured. By comparing this Fig. 7 with No. 6 we see very clearly the higher position of the lower edge of Type *B* compared with Type *A*. The aurora-corpuscles for the second type are probably of not so penetratng a kind as those for the first type. The distribution of the points having the same altitude is shown in Table 4. The geographical position of auroras of Type *B* is seen in Fig. 5, page 163.

TABLE 4.—*Distribution of Altitudes for Type B.*

Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.
91	1	99	2	107	1	115	11	122	6	129	1	137	1
92	2	100	2	108	12	116	3	123	3	.....	....	.....	....
93	0	101	3	109	6	117	8	124	4	132	1	144	1
94	0	102	1	110	9	118	8	125	3	133	1	.....	...
95	0	103	2	111	6	119	11	126	1	.....	....	146	1
96	1	104	8	112	6	120	8	127	3	135	1	.....	....
97	3	105	8	113	11	121	3	128	1	.....	....	160	1
98	1	106	2	114	6								

Between the extreme types *A* and *B* we have the bulk of the observed aurora-curtains and bands. It is difficult to distinguish special types amongst them; we therefore merely give the altitudes of all points chosen along the lower edges in order to obtain the lowest altitudes. Fig. 8 gives the result, the meaning of points and lines being the same as before. The distribution of altitudes is shown by Table 5. For the most part the curtains lay northwest, north, and northeast of Bossekop.

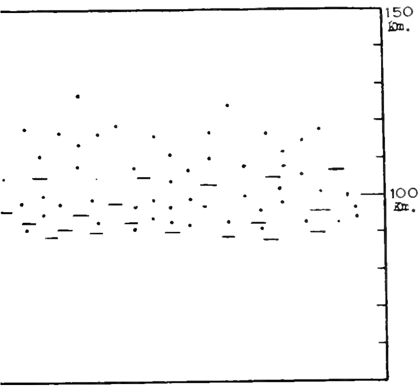


FIG. 6—Type *A*.

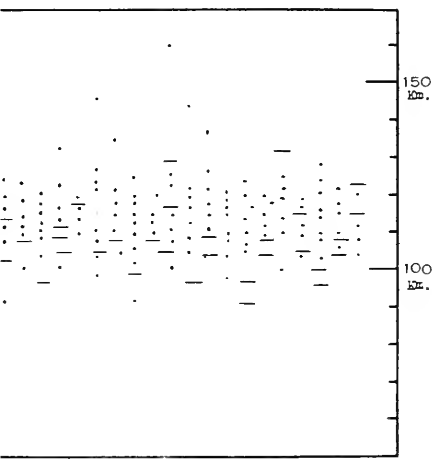


FIG. 7—Type *B*.

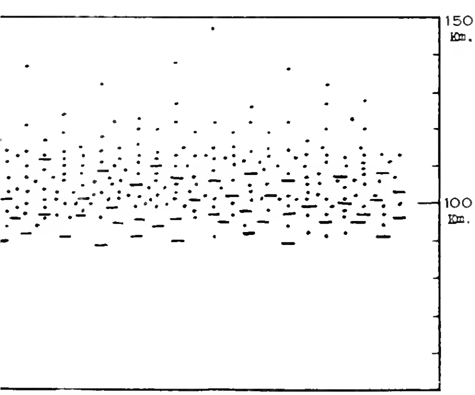


FIG. 8—Between Types *A* and *B*.

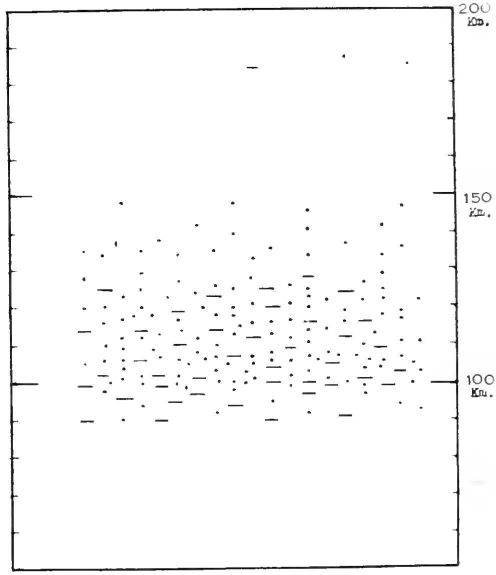


FIG. 9—Type *C*.

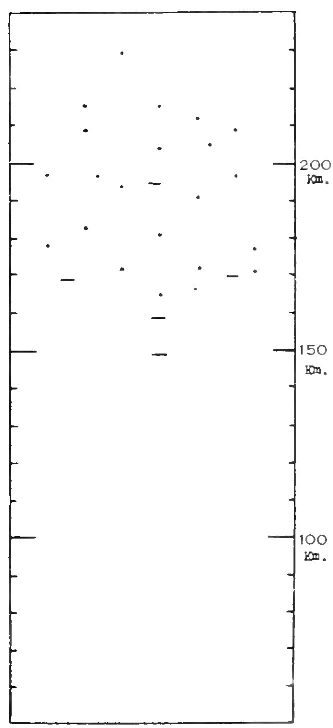


FIG. 10—Type *D*.

TABLE 5.—*Distribution of Altitudes for Auroras between Types A and B.*

Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.
89	2	96	9	103	10	110	11	117	3	124	1	.....	....
90	2	97	12	104	7	111	7	118	2	125	1	136	1
91	5	98	6	105	10	112	9	119	4	126	1	137	1
92	4	99	12	106	11	113	15	120	4	127	2	138	1
93	0	100	12	107	9	114	7	121	0	128	1	.....	....
94	6	101	17	108	9	115	8	122	7	.....	....	147	1
95	5	102	11	109	6	116	1	123	1	132	2		

When the aurora appeared near the zenith it had generally the form of *long bands* stretching from one end of the horizon to the other, and passing near the zenith. Bands like these were seen particularly on March 15, 12^h to 1^h, and on March 29, 9^h 58^m to 10^h 15^m. From a series of 15 of the most pronounced cases, the distribution of altitudes exhibited by Table 6 was obtained.

TABLE 6.—*Distribution of Altitudes for Auroras near Zenith.*

Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.
95	1	102	9	109	13	116	4	123	4	131	1	.....	....
96	2	103	10	110	9	117	3	124	2	132	1	142	1
97	2	104	10	111	6	118	3	.....	....	.....	....	.....	....
98	2	105	24	112	13	119	0	127	1	134	1	145	1
99	6	106	17	113	12	120	5	128	3	.....	....	.....	....
100	7	107	13	114	6	121	2	129	2	139	2	160	1
101	8	108	17	115	2	.....	....	130	1	140	1		

We have thus a very accentuated maximum at an altitude of 105 km. Similar bands may be seen in Pl. XI of my third communication.[5]

Type C.—*Homogeneous arches; time of exposure from 5 sec. to 60 sec.* The homogeneous tranquil arches which mostly appeared at the commencement of the aurora-displays have been photographed many times. The determination of their altitude is somewhat uncertain, partly on account of their diffuse limitation, partly because they were in general situated in the northern part of the sky, and often low down. A longer base than 27 1/2 km. would have been very useful for measuring these forms of aurora. The parallax-photographs selected—some 40 in all—gave Fig. 9, page 165. The distribution of altitudes is shown in Table 7.

[5] *Terr. Mag.*, v. 20, opposite p. 172. In the altitudes there given, those corresponding to the points 4, 13, 14, 15, 19, 20, and 21 should read, respectively, 108, 105, 105, 105, 106, 108, 108.

TABLE 7.—*Distribution of Altitudes for Type C.*

Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.
90	4	99	7	108	3	117	4	126	2	137	2	148	1
91	1	100	10	109	4	118	5	127	2	138	1	...	...
92	2	101	5	110	4	119	3	128	3	...	...	184	1
93	1	102	5	111	3	120	7	129	2	140	1	185	1
94	3	103	5	112	6	121	2	...	...	141	1	...	...
95	2	104	4	113	4	122	4	133	1	142	2	187	2
96	1	105	6	114	6	123	4	134	4	...	...		
97	3	106	10	115	1	124	2	135	3	146	1		
98	2	107	8	116	6	125	6	136	2	147	1		

The distribution of the altitudes over so great an interval seems to show that the height to which the lower border of the arches can go may vary very greatly. The faint luminosity of some of the arcs may be caused either by the very high situation of the arc or by the small quantity of aurora-corpuscles which descend in the arc; a case like this appears to be that of April 1 mentioned in the fifth communication. The very high arc that gave altitudes over 180 km. possibly belongs to the following type; the photograph was given an exposure of one minute.

Type D.—*Faint aurora-zones; exposure 1 to 2 min.* The 5 cases of this form of aurora occurred on March 3 and 4, and consisted of a very faint veil over the northern sky, limited to the south. The altitudes for points on the southern limitation gave the distribution shown in Fig. 10, page 165.

Amongst other types of which there is less material may be mentioned:

Type E.—*Isolated aurora-rays.* These rays, which are much more frequent farther south, or during maximum years, were relatively rare in 1913. A typical aurora-ray is mentioned in the fifth communication; it stretched from about 250 km. down to about 150 km. These rays should be distinguished from those caused by folds in a curtain, as in the aurora photograph of March 14.

Type F.—*Luminous tranquil areas mixed with rays and dark openings.* This type was seen only once, viz., on March 11 at 12^h 52^m to 13^h 2^m, and was described in the second communication.[6] Points chosen at the lower end of the aurora-rays gave the distribution of altitudes shown in Table 8.

[6] *Terr. Mag.*, v. 18, pp. 133-135, 1913.

TABLE 8.—*Distribution of Altitudes for Type F.*

Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.
92	1	96	1	100	1	104	2	108	0	112	1	116	1
93	1	97	1	101	4	105	0	109	1	113	0		
94	0	98	3	102	0	106	1	110	0	114	0		
95	2	99	1	103	0	107	0	111	0	115	0		

The lowest heights for each of the 5 photograms were 96, 95, 93, 92, and 101 km., respectively.

Type G.—*Corruscating auroral-bands, mostly passing through the zenith of Bossekop.* Bands like these were often seen, especially between periods of intense aurora-display, for instance, before the curtains on March 11, about midnight. Photographing was difficult because the bands did not last very long; they vanished and reappeared immediately afterwards in the neighborhood of their former position, etc. Measurement of 8 photograms gave the distribution shown in Table 9.

TABLE 9.—*Distribution of Altitudes for Type G.*

Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.	Alt. in Km.	No. of Pts.
98	1	104	1	110	2	115	2	124	1	133	1	152	1
99	0	105	7	111	1	....	....	....	....	....	....	....	....
100	0	106	4	112	1	117	1	126	1	145	1	155	1
101	1	107	6	113	2	....	....	127	1	146	2	....	....
102	3	108	2	. .	. .	123	1	....	....	....	....	162	1
103	3	109	2										

Type H.—*Corruscating surfaces of irregular forms.* One characteristic case of this kind is the aurora of March 14 at $14^h\ 26^m$, reproduced in the third communication. The three cases observed gave heights between 91 and 112 km.; the material, however, is too meager for drawing more detailed conclusions.

It will be of great interest to see whether new types of aurora will make their appearance during the years of maximum solar activity.

THE HEIGHT OF THE AURORA BOREALIS ACCORDING TO OBSERVATIONS AT THE HALDDE OBSERVATORY, NORWAY.

By L. Vegard and O. Krogness.

The Haldde Observatory, which is situated in the north of Norway on the Haldde-Top near the Alten Fjord 904 meters above sea level, was built by the Norwegian government during the years 1911-1913 on the initiative of Professor Kr. Birkeland. Its main object is to make observations and carry out research along the lines drawn in Birkeland's well-known publications on the aurora borealis, magnetic disturbances, and allied cosmic and meteorologic phenomena. In a previous publication[1] we have given the results of some height-measurements of the aurora borealis, made by us in the winter of 1912-13. In these and in later observations we have been using the photographic method first adopted by Professor Störmer in 1910[2].

In 1912-13 simultaneous photographs were taken at the Haldde Observatory by Krogness and at Vegard's station at Bossekop with a base line of 12.6 km. Since then the work has been continued at the Haldde Observatory under the direction of Krogness, and the greater part of the material collected from the years 1913-14, consisting of no less than 415 pairs of successful parallax-photographs, has been worked up by Vegard at the Physical Institute of the University of Christiania. The results, as also particulars about observations and methods of calculation, will be given in a complete report in the series of publications from the Haldde Observatory, soon to be issued. In this report will also be given reproductions and details concerning each particular aurora observed. At present we are merely going to give some statistical results considered of fundamental importance, and which we think will have far-reaching consequences with regard to the problem of the aurora.

One of the two stations necessary was always the Haldde Observatory; the position of the other station was changed according as it was found most convenient. Table 1 gives the stations, the length of the base lines, and the number of successful parallax-photographs taken at each place.

[1] Höhenbestimmungen des Nordlichts an dem Haldde-Observatorium von Oct. 1912 bis Anfang Jan. 13. *Vid. selsk. skr.* No. 11, 1914. Kristiania.

[2] C. Störmer, Bericht über eine Expedition nach Bossekop zwecks photographischer Aufnahmen und Höhenmessungen von Nordlichtern. *Vid. selsk. skr.* No. 17, 1914. Kristiania.

TABLE 1.—*Details Regarding Auroral Observations.*

Stations	Base Line	Direction from Haldde	Date of Observations	Number of Parallax-Photographs
	km.			
Haldde–Öxfjord–Alteidet	H–Ö, 39.8 H–A, 33.1	N–W W–N–W	Feb. 7, 1913	5
Haldde–Elvebakken	17.2	E–N–E	Mar. 2, 1914	4
Haldde–Gargia	26.3	S–E	Mar. 14–24, 1914	260
Haldde-Bossekop	12.5	E–N–E	Apr. 1–Nov. 26, 1914	146

In treating the observations we have paid special attention to an exact determination of the bottom edge of the aurora, so as to find with the greatest possible accuracy the height to which the cosmic rays can penetrate down into the atmosphere. This lower limit is also generally very sharp, while upwards luminosity more gradually fades away; and the upper limit is consequently not so well defined. In fact the photographic method is liable to give too small values for the upper limit, because the very faintest light gives no impression on the plate.

From the discussion of the observations, 2,487 determinations of the height of different auroræ were obtained, the following different types of aurora having been separately studied:

1. Diffuse arcs; 2. drapery-shaped arcs; 3. typical draperies; 4. splitted bands; 5. rays; and 6. diffuse pulsating light areas.

We have also treated separately the Haldde-Bossekop observations and the Haldde-Gargia ones in order to ascertain whether the results may vary with time and change of base line. The mean values for the upper and lower limits of the aurora are given in the following Tables 2 and 3:

TABLE 2.—*Upper Limit of the Aurora.*

Form	Haldde-Gargia		Haldde-Bossekop		Total	
	Number	Height	Number	Height	Number	Height
		km.		km.		km.
Diffuse Arcs	57	144.5		. .	57	144.5
Drapery-shaped Arcs	72	168.9	117	177.2	189	174.3
Draperies	56	160.2	158	180.0	214	174.8
Rays	23	252.8	23	227.5	46	240.3

TABLE 3.—*Lower Limit of the Aurora.*

Form	Haldde-Gargia		Haldde-Bossekop		Total	
	Number	Height	Number	Height	Number	Height
		km.		km.		km.
Diffuse Arcs	355	109.3	6	113.5	361	109.4
Drapery-shaped Arcs	620	105.6	397	108.0	1017	106.5
Draperies	175	112.0	239	109.3	414	110.2
Rays	26	114	25	117	51	115.5
Splitted Bands	43	114			43	114
Pulsating Areas	34	104			34	104

The upper limit of the aurora is found to vary from about 100 *km. up to* 330 *km.* The very low limits belong to arcs and draperies. The highest values are found for the ray form, which will also be apparent from the average values given in Table 2.

Comparing the average values of the *height of the bottom edge*, we find that both base lines give very nearly the same values. We further notice the remarkable fact that the average height is very nearly equal for the more frequent forms of aurora. Only the rays and probably the splitted bands give a somewhat higher value than the rest. This result would indicate that probably all the forms considered are essentially of the same nature. The fact that the rays do not descend so low as arcs and draperies is somewhat striking and contrary to the impression one gets from a direct examination of an auroral display. *The average of all measurements (1920) of the height of the bottom edge of the aurora is* 108.2 *km.* The determinations given in our previous publication[3] give an average of 111.5 km. (weighted mean 109.1 km.). In view of the limited number of measurements on which the latter number is based, the agreement is remarkably good, and does not indicate any change of height from one year to another. It should likewise be mentioned that these values also agree well with the latest observations of Störmer from the spring of 1913.

We have also found for the various types how the auroras are distributed at the different heights. For this purpose the following procedure was adopted. The height-interval was divided into equal intervals of two km., and the number of auroras with their

[3] Höhenbestimmungen des Nordlichts an dem Haldde-Observatorium von Oct. 1912 bis Anfang Jan. 13. *Vid. selsk. skr.* No. 11, 1914, Kristiania.

lower limits inside each of these intervals was counted. The results are given in Table 4.

TABLE 4.—*Distribution of Auroras According to Height.*

Height-Intervals.	Diffuse Arcs.	Drapery-shaped Arcs.	Draperies.	Rays.	Splitted Bands.	Pulsating Auroras.	Total Number (Haldde-Gargia).	Total Number (Haldde-Bossekop).	Total of All Measured Lower Limits.
km.									
85–87	2	5	...		...		7	...	7
87–89	5	5	7		2		8	11	19
89–91	5	15	5	...	1	...	16	10	26
91–93	4	22	10	...	2	1	21	17	38
93–95	9	26	14	...	1	2	33	18	51
95–97	15	52	17	...	2	2	61	27	88
97–99	10	73	25	...	3	3	69	44	113
99–101	24	132	45	1	4	7	131	78	209
101–103	17	71	25	...	0	6	76	44	120
103–105	23	77	32	...	3	5	100	41	141
105–107	44	115	44	2	4	1	151	63	214
107–109	35	81	25	6	...	4	108	40	148
109–111	30	61	20	10	5	2	96	34	130
111–113	27	55	20	4	...	1	68	40	108
113–115	17	60	12	3	...		60	33	93
115–117	17	40	14	4	...		45	30	75
117–119	11	23	15	5	1		35	20	55
119–121	15	18	9	6	1	...	31	18	49
121–123	13	15	9	2	1		29	11	40
123–125	11	25	7	2			26	19	45
125–127	5	9	5	3			13	9	22
127–129	4	6	5	1			11	5	16
129–131	5	8	1		3		11	7	18
131–133	4	6	2				5	8	13
133–135	2	6	4	1	1		5	8	17
135–137	2	3	1				3	4	7
137–139	3	3	6	1	1		6	7	13
139–141	2	1	5		3		9	2	11
141–143		1	5				3	3	6
143–145			3		1		2	2	4
145–147			2				1	1	2
147–149		2	4		1		3	4	7
149–151			3		1		2	2	4
151–153		1	2		1		2	2	4
153–155			3		1		2	2	4
155–157			1				...	1	1
157–159			...		...		...	...	...
159–161			...					...	...
161–163			2				1	1	2
163–165							...	...	...
165–167			4				3	1	4

In examining these numbers it should be kept in mind that, for various reasons, there may in some cases be errors of several kilometers attached to the measurements; only under the best possible conditions may the error be of the order of 1 km. If any peculiar law

with regard to the distribution in altitude of the aurora exists, we can not expect to find it with certainty unless there are a large number of measurements available. For the three most frequent forms this number is quite large, and for this case the distribution is represented in the curves, Fig. 1. Curve I represents the distribution of diffuse arcs: II, the distribution of draperies; III, that of drapery-formed arcs; and IV, that for the total number of measurements.

We notice that *most auroras appear at a height of* 100-110 *km.;* no aurora lower than 85 km. has been found, and these smallest values are always somewhat doubtful. *The most striking feature of the curves in Fig.* 1 *is the existence of two well-defined maxima, the one at a height of* 100 *km., the second at* 106 *km.*

Curve III of Fig. 1 shows two other maxima at 114 and 124 km., but merely from the present material we should not venture to conclude that these maxima are real, although more than the two principal maxima may very likely exist. The two principal maxima, however, are very marked, indeed, and they are found for all the more frequent forms; and, as is seen from Fig. 2, the same maxima also comes out most distinctly if we consider separately the observations from Haldde-Gargia (II, Fig. 2) and those from Haldde-Bossekop (I, Fig. 1.).

Curves which have been drawn by Professor Störmer[4], based on his observations in the spring of 1913, also give indication of the maxima; but we think that the present results give an incontestable proof of their existence.

The existence of these maxima, which seems to remain unaltered from one year to another, is a fact of far-reaching importance. The immediate conclusion we must draw is, *that a predominant part of the cosmic rays coming from the Sun and producing the aurora-borealis is made up of two groups, each of which has its own quite definite penetrating power. The fact that the diffuse arcs, the drapery-shaped arcs, and the draperies all give the same principal maxima affords evidence that these most frequent forms are essentially of the same physical nature and must be produced by the same kind of rays.*

With regard to the three less frequent forms, we have not yet a sufficient number of observations to draw any entirely certain conclusions; the small differences in the average height of the aurora, however, indicates that all forms are produced by the same type of rays. If so, the various types should mainly differ with regard to the shape of the area of precipitation of the cosmic rays.

[4] Refer to paper read before the Scandinavian Science Congress at Christiania, July, 1916 [See also *Terr. Mag.*, v. 21, p. 160.—Ed.]

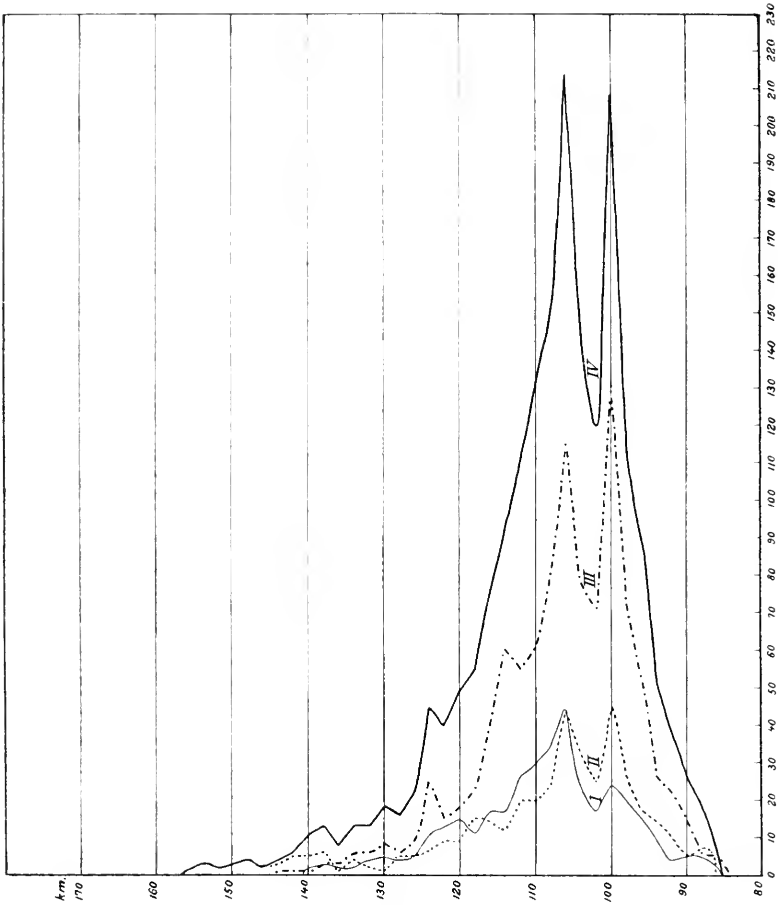

km.
170
160
150
140
130
120
110
100
90
80
IV
III
II
I
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230

FIG. 1.

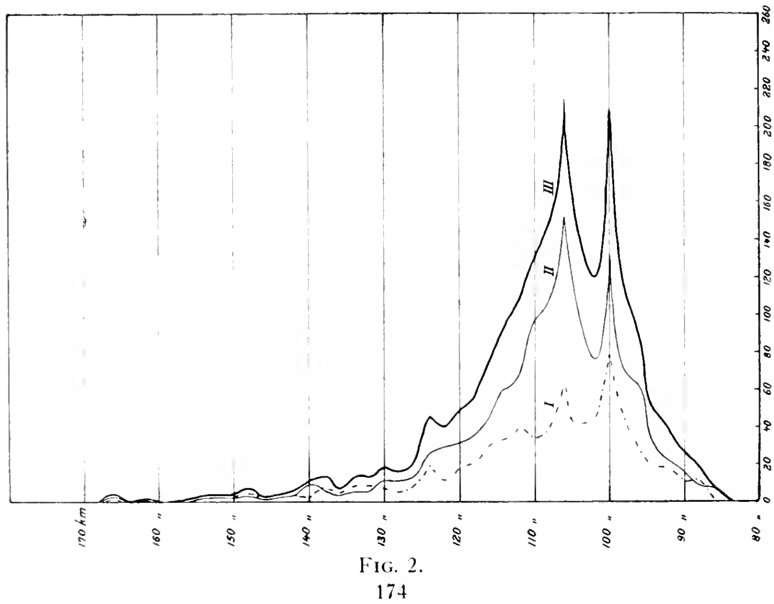

170 km
160 "
150 "
140 "
130 "
120 "
110 "
100 "
90 "
80 "
III
II
I
0
20
40
60
80
100
120
140
160
180
200
220
240
260

FIG. 2.

MAGNETIC DECLINATIONS OBSERVED ON THE CARNEGIE FROM SAMOA TO GUAM AND SAN FRANCISCO, JUNE—SEPTEMBER, 1916.[1]

By J. P. Ault, Commanding the *Carnegie*.

(*Minus sign indicates west declination, and plus, east declination.*)

Date	Position: Latitude	Position: Longitude	Carnegie	Chart Values[2]: Brit.	Chart Values[2]: Ger.	Chart Values[2]: U. S.	Chart Corrections: Brit.	Chart Corrections: Ger.	Chart Corrections: U. S.
1916	° ′	° ′	°	°	°	°	°	°	°
June 19	14 17 S	170 54 W	+10.1	+10.0	+ 9.5	+ 9.9	+ 0.1	+ 0.6	+ 0.2
20	12 32 S	171 02 W	+ 9.6	+ 9.8	+ 9.3	+ 9.7	− 0.2	+ 0.3	− 0.1
20	11 15 S	170 42 W	+ 9.4	+ 9.6	+ 9.1	+ 9.6	− 0.2	+ 0.3	− 0.2
21	9 34 S	170 32 W	+ 8.9	+ 9.4	+ 9.0	+ 9.4	− 0.5	− 0.1	− 0.5
21	8 56 S	170 38 W	+ 8.8	+ 9.3	+ 8.9	+ 9.3	− 0.5	− 0.1	− 0.5
22	7 15 S	170 54 W	+ 8.9	+ 9.2	+ 8.8	+ 9.2	− 0.3	+ 0.1	− 0.3
22	5 51 S	171 25 W	+ 8.6	+ 9.1	+ 8.7	+ 9.2	− 0.5	− 0.1	− 0.6
23	4 19 S	171 59 W	+ 9.0	+ 9.0	+ 8.7	+ 9.2	0.0	+ 0.3	− 0.2
23	3 02 S	172 14 W	+ 8.6	+ 9.0	+ 8.7	+ 9.2	− 0.4	− 0.1	− 0.6
24	1 51 S	172 51 W	+ 8.4	+ 9.0	+ 8.7	+ 9.2	− 0.6	− 0.3	− 0.8
24	0 55 S	173 15 W	+ 8.5	+ 9.0	+ 8.7	+ 9.0	− 0.5	− 0.2	− 0.5
25	0 17 N	173 49 W	+ 8.7	+ 9.1	+ 8.8	+ 9.0	− 0.4	− 0.1	− 0.3
25	0 52 N	174 02 W	+ 8.6	+ 9.1	+ 8.9	+ 9.0	− 0.5	− 0.3	− 0.4
26	1 42 N	174 55 W	+ 8.6	+ 9.2	+ 8.9	+ 9.0	− 0.6	− 0.3	− 0.4
26	2 40 N	175 50 W	+ 8.3	+ 9.2	+ 9.0	+ 9.0	− 0.9	− 0.7	− 0.7
27	3 54 N	176 48 W	+ 9.2	+ 9.2	+ 9.2	+ 9.0	0.0	0.0	+ 0.2
27	5 10 N	177 23 W	+ 8.9	+ 9.2	+ 9.3	+ 9.0	− 0.3	− 0.4	− 0.1
28	6 48 N	178 04 W	+ 8.8	+ 9.2	+ 9.4	+ 9.0	− 0.4	− 0.6	− 0.2
28	8 15 N	178 38 W	+ 9.0	+ 9.5	+ 9.6	+ 9.1	− 0.5	− 0.6	− 0.1
29	9 49 N	179 20 W	+ 9.2	+ 9.5	+ 9.7	+ 9.1	− 0.3	− 0.5	+ 0.1
29	11 11 N	179 50 E	+ 9.4	+ 9.5	+ 9.8	+ 9.2	− 0.1	− 0.4	+ 0.2
July 1[3]	12 44 N	179 13 E	+ 9.1	+ 9.5	+ 9.8	+ 9.2	− 0.4	− 0.7	− 0.1
1	13 17 N	178 52 E	+ 8.4	+ 9.5	+ 9.8	+ 9.2	− 1.1	− 1.4	− 0.8
2	14 29 N	177 36 E	+ 9.1	+ 9.4	+ 9.7	+ 9.1	− 0.3	− 0.6	0.0
2	15 03 N	176 23 E	+ 9.0	+ 9.3	+ 9.6	+ 9.0	− 0.3	− 0.6	0.0
3	15 35 N	174 39 E	+ 9.0	+ 9.1	+ 9.3	+ 8.7	− 0.1	− 0.3	+ 0.3
4	16 04 N	172 48 E	+ 8.6	+ 8.7	+ 8.9	+ 8.4	− 0.1	− 0.3	+ 0.2
4	16 36 N	171 37 E	+ 8.1	+ 8.5	+ 8.7	+ 8.2	− 0.4	− 0.6	− 0.1
5	17 06 N	170 37 E	+ 8.0	+ 8.3	+ 8.5	+ 8.0	− 0.3	− 0.5	0.0
5	17 37 N	169 32 E	+ 7.5	+ 8.1	+ 8.2	+ 7.7	− 0.6	− 0.7	− 0.2
6	18 06 N	167 59 E	+ 7.3	+ 7.7	+ 7.7	+ 7.3	− 0.4	− 0.4	0.0
6	18 33 N	167 01 E	+ 6.7	+ 7.4	+ 7.4	+ 7.0	− 0.7	− 0.7	− 0.3
7	19 12 N	165 46 E	+ 6.5	+ 7.1	+ 7.1	+ 6.6	− 0.6	− 0.6	− 0.1
7	19 41 N	164 41 E	+ 6.7	+ 6.8	+ 6.6	+ 6.3	− 0.1	+ 0.1	+ 0.4
8	20 17 N	163 30 E	+ 6.0	+ 6.3	+ 6.2	+ 5.9	− 0.3	− 0.2	+ 0.1
8	20 24 N	162 36 E	+ 5.2	+ 6.0	+ 6.0	+ 5.6	− 0.8	− 0.8	− 0.4
9	20 31 N	161 44 E	+ 4.9	+ 5.8	+ 5.7	+ 5.4	− 0.9	− 0.8	− 0.5
9	20 22 N	160 43 E	+ 4.8	+ 5.5	+ 5.1	+ 5.2	− 0.7	− 0.3	− 0.4
10	20 07 N	159 56 E	+ 4.4	+ 5.4	+ 5.1	+ 5.0	− 1.0	− 0.7	− 0.6
10	19 49 N	158 59 E	+ 4.1	+ 5.2	+ 4.9	+ 4.8	− 1.1	− 0.8	− 0.7
11	19 29 N	158 05 E	+ 4.1	+ 5.0	+ 4.8	+ 4.6	− 0.9	− 0.7	− 0.5
11	19 08 N	157 11 E	+ 3.7	+ 4.8	+ 4.5	+ 4.3	− 1.1	− 0.8	− 0.6
12	18 28 N	155 51 E	+ 3.6	+ 4.4	+ 4.2	+ 4.1	− 0.8	− 0.6	− 0.5
12	17 55 N	154 44 E	+ 3.2	+ 4.2	+ 4.0	+ 3.8	− 1.0	− 0.8	− 0.6
13	17 20 N	153 29 E	+ 3.0	+ 4.0	+ 3.7	+ 3.6	− 1.0	− 0.7	− 0.6
13	16 50 N	152 23 E	+ 3.2	+ 3.7	+ 3.5	+ 3.3	− 0.5	− 0.3	− 0.1
14	16 13 N	151 10 E	+ 2.7	+ 3.6	+ 3.3	+ 3.2	− 0.9	− 0.6	− 0.5
14	15 39 N	150 07 E	+ 2.5	+ 3.4	+ 3.1	+ 3.0	− 0.9	− 0.6	− 0.5
15	14 54 N	148 41 E	+ 2.5	+ 3.3	+ 2.9	+ 2.9	− 0.8	− 0.4	− 0.4
15	14 32 N	147 32 E	+ 2.2	+ 3.1	+ 2.7	+ 2.6	− 0.9	− 0.5	− 0.4
16	13 54 N	145 38 E	+ 1.9	+ 2.8	+ 2.3	+ 2.4	− 0.9	− 0.4	− 0.5
16	13 52 N	145 30 E	+ 2.1	+ 2.8	+ 2.3	+ 2.3	− 0.7	− 0.2	− 0.2
17[4]	13 35 N	144 39 E	+ 2.1	+ 2.7	+ 2.2	+ 2.2	− 0.6	− 0.1	− 0.1

[1] For previous tables, see footnote 1, *Terr. Mag.*, v. 21, p. 109. [2] British Admiralty Chart No. 2598 for 1912, referred to 1916; Reichs-Marine-Amt. Chart Tit. XIV, No. 2, for 1910, referred to 1916 by means of secular changes on U. S. Chart; U. S. Hydrographic Office Chart No. 2406 for 1915, referred to 1916. [3] Crossed 180th meridian, omitting the date June 30.
[4] At Port Apra, Guam, until August 7, 1916.

MAGNETIC DECLINATIONS—(*Continued*).

Date	Position		Carnegie	Chart Values[2]			Chart Corrections		
	Latitude	Longitude		Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1916	° ′	° ′	°	°	°	°	°	°	°
Aug. 8	14 38N	144 25 E	+ 1.3	+ 2.6	+ 2.0	+ 1.9	− 1.3	− 0.7	− 0.6
10	17 26N	144 33 E	+ 0.7	+ 2.0	+ 1.4	+ 1.4	− 1.3	− 0.7	− 0.7
11	18 10N	144 14 E	+ 0.8	+ 1.7	+ 1.1	+ 1.2	− 0.9	− 0.3	− 0.4
12	19 12N	143 36 E	+ 0.7	+ 1.2	+ 0.8	+ 0.8	− 0.5	− 0.1	− 0.1
13	23 03N	144 27 E	− 0.5	+ 0.4	0.0	− 0.2	− 0.9	− 0.5	− 0.3
14	26 29N	144 35 E	− 1.6	− 0.8	− 1.0	− 1.4	− 0.8	− 0.6	− 0.2
14	26 34N	144 34 E	− 1.6	− 0.8	− 1.0	− 1.5	− 0.8	− 0.6	− 0.1
14	27 38N	144 14 E	− 2.0	− 1.2	− 1.2	− 2.0	− 0.8	− 0.8	0.0
15	29 32N	144 07 E	− 2.7	− 1.8	− 1.8	− 2.5	− 0.9	− 0.9	− 0.2
15	30 14N	144 06 E	− 2.7	− 2.1	− 2.1	− 2.7	− 0.6	− 0.6	0.0
16	30 14N	144 27 E	− 2.7	− 2.0	− 2.0	− 2.6	− 0.7	− 0.7	− 0.1
16	30 34N	144 07 E	− 3.0	− 2.2	− 2.2	− 2.8	− 0.8	− 0.8	− 0.2
17	31 49N	143 31 E	− 3.3	− 2.7	− 2.8	− 3.2	− 0.6	− 0.5	− 0.1
19	36 12N	149 58 E	− 3.3	− 2.4	− 2.0	− 3.0	− 0.9	− 1.3	− 0.3
20	38 17N	153 31 E	− 2.7	− 1.8	− 1.4	− 2.4	− 0.9	− 1.3	− 0.3
20	38 25N	153 43 E	− 2.4	− 1.8	− 1.3	− 2.3	− 0.6	− 1.1	− 0.1
21	40 11N	156 28 E	− 1.9	− 1.1	− 1.0	− 1.5	− 0.8	− 0.9	− 0.4
22	42 41N	158 15 E	− 1.7	− 0.9	− 0.8	− 1.2	− 0.8	− 0.9	− 0.5
22	43 13N	158 40 E	− 1.5	− 0.9	− 0.8	− 1.0	− 0.6	− 0.7	− 0.5
23	44 24N	158 59 E	− 1.5	− 1.0	− 0.9	− 1.1	− 0.5	− 0.6	− 0.4
23	45 21N	159 32 E	− 1.7	− 1.0	− 0.8	− 1.1	− 0.7	− 0.9	− 0.6
24	46 20N	160 12 E	− 1.3	− 0.8	− 0.5	− 0.9	− 0.5	− 0.8	− 0.4
25	46 54N	162 58 E	− 0.5	+ 0.2	+ 0.6	+ 0.4	− 0.7	− 1.1	− 0.9
25	46 57N	163 27 E	− 0.1	+ 0.4	+ 0.9	+ 0.7	− 0.5	− 1.0	− 0.8
26	47 03N	165 21 E	+ 0.3	+ 1.1	+ 1.6	+ 1.4	− 0.8	− 1.3	− 1.1
27	47 14N	166 54 E	+ 1.8	+ 1.7	+ 2.2	+ 2.2	+ 0.1	− 0.4	− 0.4
27[5]	47 15N	167 13 E	+ 1.7	+ 2.0	+ 2.4	+ 2.4	− 0.3	− 0.7	− 0.7
27	47 20N	168 10 E	+ 2.3	+ 2.6	+ 2.8	+ 2.8	− 0.3	− 0.5	− 0.5
28	47 25N	169 02 E	+ 1.8	+ 3.0	+ 3.2	+ 3.2	− 1.2	− 1.4	− 1.4
28	47 28N	169 40 E	+ 3.3	+ 3.4	+ 3.5	+ 3.5	− 0.1	− 0.2	− 0.2
29	47 46N	172 03 E	+ 4.0	+ 4.6	+ 4.5	+ 4.7	− 0.6	− 0.5	− 0.7
30	48 09N	174 24 E	+ 5.4	+ 5.7	+ 5.6	+ 5.8	− 0.3	− 0.2	− 0.4
30[6]	49 00N	179 37W	+ 8.5	+ 8.7	+ 8.8	+ 8.8	− 0.2	− 0.3	− 0.3
31	49 34N	177 13W	+10.1	+10.0	+ 9.9	+ 9.8	+ 0.1	+ 0.2	+ 0.3
Sept. 1	49 58N	175 23W	+11.1	+11.0	+10.9	+10.7	+ 0.1	+ 0.2	+ 0.4
2	50 46N	173 04W	+12.1	+12.2	+12.2	+12.0	− 0.1	− 0.1	+ 0.1
3	51 22N	168 56W	+14.3	+14.6	+14.2	+14.5	− 0.3	+ 0.1	− 0.2
3	51 38N	167 07W	+15.4	+15.5	+15.2	+15.5	− 0.1	+ 0.2	− 0.1
4	51 55N	164 26W	+16.6	+16.8	+16.5	+16.9	− 0.2	+ 0.1	− 0.3
5	52 28N	161 21W	+17.9	+18.2	+17.8	+18.2	− 0.3	+ 0.1	− 0.3
5	52 47N	159 46W	+18.7	+18.8	+18.7	+18.8	− 0.1	0.0	− 0.1
6	53 22N	156 29W	+20.4	+20.4	+20.2	+20.2	0.0	+ 0.2	+ 0.2
7	52 57N	151 50W	+21.9	+21.9	+22.0	+21.9	0.0	− 0.1	0.0
8	51 16N	146 46W	+22.2	+22.7	+23.0	+23.0	− 0.5	− 0.8	− 0.8
9	49 49N	144 32W	+23.3	+22.6	+22.9	+22.8	+ 0.7	+ 0.4	+ 0.5
10	47 42N	141 45W	+22.7	+22.1	+22.6	+22.4	+ 0.6	+ 0.1	+ 0.3
10	46 49N	140 51W	+22.5	+21.9	+22.2	+22.3	+ 0.6	+ 0.3	+ 0.2
11	45 37N	139 32W	+21.9	+21.4	+21.7	+21.8	+ 0.5	+ 0.2	+ 0.1
11	45 26N	139 21W	+21.3	+21.3	+21.7	+21.8	0.0	− 0.4	− 0.5
12	43 44N	138 25W	+20.9	+20.4	+20.7	+21.2	+ 0.5	+ 0.2	− 0.3
12	42 26N	138 11W	+20.1	+19.8	+20.2	+20.5	+ 0.3	− 0.1	− 0.4
13	41 42N	138 17W	+20.2	+19.4	+19.7	+20.1	+ 0.8	+ 0.5	+ 0.1
14	40 51N	138 14W	+19.7	+18.9	+19.3	+19.7	+ 0.8	+ 0.4	0.0
15	40 48N	138 06W	+19.9	+18.9	+19.2	+19.7	+ 1.0	+ 0.7	+ 0.2
15	40 47N	137 33W	+19.5	+19.0	+19.2	+19.7	+ 0.5	+ 0.3	− 0.2
16	40 41N	135 56W	+19.8	+19.1	+19.3	+19.8	+ 0.7	+ 0.5	0.0
16	40 38N	134 22W	+19.2	+19.2	+19.4	+20.0	0.0	− 0.2	− 0.8
17	40 23N	132 09W	+19.8	+19.2	+19.3	+19.9	+ 0.6	+ 0.5	− 0.1
17	39 56N	130 33W	+19.6	+19.2	+19.1	+19.6	+ 0.4	+ 0.5	0.0
18	39 41N	129 55W	+19.5	+19.1	+19.0	+19.5	+ 0.4	+ 0.5	0.0
21[7]	37 46N	122 35W	+18.8	+18.5	+17.9	+18.1	+ 0.3	+ 0.9	+ 0.7

[5] Swinging ship. [6] Crossed 180th meridian, repeating the date Aug. 30. [7] Arrived at San Francisco on Sept. 21.

METEOROLOGISCHE UND LUFTELEKTRISCHE MESSUNGEN WAEHREND DER TOTALEN SONNENFINSTERNIS AM 10. OKTOBER 1912 AUF DER FACENDA BOÀ VISTA BEI CHRISTINA (PROV. MINAS GERAES-BRASILIEN). II.—LUFTELEKTRISCHE BEOBACHTUNGEN.

VON W. KNOCHE UND J. LAUB.

Zur Registrierung der luftelektrischen Vorgänge standen uns die folgenden Apparate zur Verfügung:

1. Zur Registrierung *Hertzscher Wellen* ein Turpainscher Gewitterregistrator mit Milliampèremeter der Firma Richard-Paris mit täglicher Umdrehung.
2. Zur Bestimmung des *radioaktiven Gehalts* der Luft ein komplettes Instrumentarium nach Elster und Geitel (Drahtmethode) von der Firma Günther und Tegetmeyer (Braunschweig), welche auch die übrigen Elektroskope geliefert hatte.
3. Zur Registrierung des *Potentialgefälles* ein mechanisch registrierendes Benndorf-Quadranten-Elektrometer mit Potsdamer automatischer Umschaltung und Ioniumkollektor.[17]
4. Zur Registrierung der *Leitfähigkeit* ein Quadranten-Elektrometer wie vorher mit 20 m langem Zerstreuungsdraht innerhalb eines geerdeten Drahtcylinders und Umschaltung für beide Vorzeichen. Zur direkten Messung der Leitfähigkeit (Zerstreuungsmethode von Elster und Geitel) standen zwei Wulfsche Elektroskope, je eins für jedes Vorzeichen, zur Verfügung; zu ihrer Aichungskontrolle dienten zwei Krügerbatterien.
5. Zur Bestimmung der *Luftladung* in E. S. E., resp. zur Bestimmung der *Ionenzahl*, zählten wir mit zwei Ebertschen Aspirationsapparaten, je einem für jedes Vorzeichen.

Alle Registrierapparate befanden sich in einem ebenerdigen kleinen Holzhäuschen auf schweren Tischen montiert. Das Häuschen hatte eine Tür nach dem vorher erwähnten Hof mit der meteorologischen Aufstellung, eine andere gegenüberliegend nach einem verwilderten, ausgedehnten Garten, in dem zahlreiche niedrige Apfelsinenbäume standen.

MITTLERER ZUSTAND DER LUFTELEKTRISCHEN ELEMENTE IN BOÀ VISTA.

Bevor wir auf die luftelektrischen Verhältnisse während der Finsternis eingehen, seien kurz die Messungen an den übrigen Tagen besprochen.

Hertzsche Wellen. Als Antenne benutzten wir drei vom Kohärer ausgehende Kupferdrähte, welche mittelst Gockelscher Isolatoren

[17] S. LUEDELING, l. c. 6, S. 34-37, und *Ergebnisse Meteor. Beobacht. in Potsdam im Jahre 1904*

an 8 m hohen Bambusrohren befestigt waren, so dass ihre Gesamtlänge 24 m betrug. Es verging kein Tag, an dem nicht Aufzeichnungen von Hertzschen Wellen zur Registrierung gelangten (s. Tabelle 7), obwohl Gewitter oder gewitterähnliche Erscheinungen nicht beobachtet wurden. Die meisten trafen am 5. und 6. Oktober ein (10 resp. 9 Registrierungen), die wenigsten am 7. und 8. Oktober (3 Registrierungen). Meteorologisch stärker unterschieden sind diese vier Tage kaum von einander; sie alle waren regenlos und branddunstig. Vom 3.—12. Oktober wurde die immerhin nicht geringe Zahl von 52 Entladungen aufgenommen, oder im Mittel etwa 6 in je 24 Stunden.

Die grösste Stundenmenge betrug 5 Entladungen; unter 230 Registrierstunden überhaupt gab es 36 oder 16% mit Entladungen. Ein täglicher Gang ist nach nur 9 vollständigen Registriertagen bei einem so willkürlichen Element nicht abzuleiten. Es scheint aber fast, als ob die Zeit zwischen 6p und 6a, also die Nacht, sehr entladungsarm, resp. entladungsfrei ist, während zwischen 7a—9a ein Entladungsmaximum liegt. Zwischen 7a—8a finden an allen Tagen Entladungen statt. Als Ursache der Entladungen könnte man vielleicht an Gewitter denken, die in der Serra de Mantiqueira herrschen, doch widerspricht dem die Tageszeit der häufigsten Entladungen; in diesen Morgenstunden findet allgemein ein Minimum im täglichen Gewitterverlaufe statt. Man ersieht jedenfalls auch aus dieser so kurzen Beobachtungsreihe, wie wichtig Registrierungen atmosphärischer Wellen in vielen Teilen der Erde wären. Sie haben in Südamerika schon auffällige Resultate ergeben.[18]

Neben den Entladungen, welche ein Fritten des Kohärers, das durch Klopfen erst wieder beseitigt werden muss, bewirken, trat noch eine andere Erscheinung auf, die übrigens auch in Santiago (Chile) beobachtet wurde. Es besteht keine vollständige Frittung, wohl aber wird der Widerstand "unendlich" des Kohärers aufgehoben, so dass ein schwacher Strom den Kohärer passiert und auf das zwischen Kohärer und Element geschaltete Milliampèremeter einwirkt. In Tabelle 7 wurde eine derartige Widerstandsverminderung mit 0 bezeichnet, in Tabelle 8 ist von 15 zu 15 Minuten die vom Kohärer durchgelassene Stromstärke in Milliampère angegeben und obendrein der Mittelwert der betreffenden Stunde.

[18] S. W. KNOCHE, Registr. Hertzscher Wellen in S. Carlos de Ancud in Publ. No. 9 d. *Inst. Centr. Meteor. i Geofis. de Chile*, 1914. S. 5-19.

TABELLE 7.—*Aufzeichnungen von Hertzschen Wellen in Boa Vista, 2.—11. Oktober 1912.*
(0 deutet an, dass das Milli-Ampèremeter reaktionierte, ohne dass eine völlige Frittung eintrat.)

DATUM	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	TAGES-SUMME
2. Okt.																3	3			1	2				...
3. "						1	1	2				1													5
4. "								3							1										4
5. "				2			1	1			2		2	2	0	0	0	0	0	0	0	0	0	0	10
6. "	0	0	1	0	0	0	0	3	5																9
7. "							0	1	1	1															3
8. "								2					1												3
9. "							1	3					1												5
10. "							1	1	2	1					3										8
11. "							0	0	2						1	1				1					5
Summe 3.-11. Okt.	0	0	1	2	0	1	4	16	10	2	2	1	4	2	5	1	0	0	0	1	0	0	0	0	52

TABELLE 8. *Stundenmittel der Ströme in Milli-Ampère, die das Milli-Ampèremeter des Gewitterregistrierapparats passieren, in Boa Vista, 3.–11. Oktober 1912.*
(0 = 1 M. A.)

DATUM	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	TAGES-MITTEL
3. Okt.																									
4. "																									
5. "													4	6	11	24	26	26	26	24	25	25	24	25	10.2
6. "	22	21	18	20	20	20	13	0	0																5.6
7. "							0																		0.0
8. "																									
9. "																									
10. "																									
11. "							0	1	0																0.0
Mittel 3.-11. Okt.	2.4	2.3	2.0	2.2	2.2	2.2	1.4	0.1	0.0				0.4	0.7	1.1	2.5	2.9	2.9	2.9	2.7	2.8	2.8	2.7	2.8	1.8

TABELLE 9. *Werte der Potentialgefälle (Volt/meter) in Boa Vista, 5.–10. Oktober 1912.*
(*r* = ruhiger, *m* = mässig bewegter, *u* = unruhiger Kurvenverlauf.)

DATUM	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	TAGES-MITTEL
5. Okt.											18*r*	18*r*	12*r*	11*r*	16*r*	20*r*	20*r*	10*u*	36*u*	67*u*	37*u*	42*u*	25*u*	25*m*	
6. "	16*m*	38*m*	48*m*	32*u*	54*m*	66*m*	62*r*	66*r*	110*m*	79*m*	86*m*	180*m*	52*m*	15*m*	200*u*	300*m*	30*u*	60*u*	78*r*	78*m*	66*m*	84*m*	54*m*	54*r*	77*m*
7. "	61*r*	63	69	60	52*r*								22*m*	67*m*	128*m*	134*r*	95*r*	17*u*	16*u*	13*m*	19*u*	20*u*	31*m*	13*m*	
8. "	26*r*	39*m*	40*m*	54*m*	47*m*	52*r*	17*r*	11*r*	17*r*	29*r*	29*r*	41*r*	30*r*	32*m*	37*m*	46*m*	37*m*	30*m*	54*m*	52*m*	35*r*	24*m*	7*r*	7*r*	40*m*, *r*
9. "	5*m*	5*r*	10*m*	11*r*	10*r*	10*r*	12*m*	13*r*	6*m*	11*r*	6*r*	9*m*	28*m*	61*m*	67*m*	5*m*	55*r*	37*r*	−7*m*	2*m*	6*m*	7*r*	8*r*	9*r*	8*m*
10. "	9*r*	9*r*	9*r*	9*r*	7*m*	6*r*	3*m*	7*r*	5*r*	5*m*	5*r*	6*r*	6*r*	5*r*	4*m*	4*r*	6*r*	5*r*	5*r*	6*r*					(6)*r*
Mittel 6., 8. u. 9.	16*m*	27*m*	33*m*	36*m*	37*m*	43*r*	40*r*	30*r*	44*m*	40*r*	40*m*	77*m*	18*m*	36*m*	57*m*	117*m*	41*m*	42*m*	12*m*	44*m*	36*m*	38*m*	23*r*	23*r*	42*m*
																						Aller	Stunden		35*r*

Hierbei wird keineswegs wie beim völligen Fritten (Erregung des Elektromagneten) durch (automatisches) Klopfen die Widerstandsverminderung aufgehoben, und der Stromdurchgang auf 0 gebracht, sondern der Widerstand wird entweder von selbst kleiner oder selbständig grösser, gegebenen Falles wiederum unendlich, scheinbar dem Ansprechen eines äusseren Reizes auf den Fritter folgend. Es ist nicht unmöglich dass sehr schwache oder sehr entfernte Entladungen ein derartiges Verhalten bedingen. In unserem Falle setzte diese "Durchlässigkeit" des Kohärers am 5. nachmittags ein und stieg von 0 (= kaum merklicher Stromdurchgang) unter kleinen Schwankungen bis 4p auf 25 M. A., um sich bis Mitternacht auf ungefähr dieser Höhe zu halten. Darauf, am 6., trat ein Abfall auf rund 20 M. A. ein, dann, nach einigen Stunden der Konstanz und zwischen 6a–7a, ein schnelles Sinken von 20 auf 0 M. A. Also an den Tagen der zahlreichsten Entladungen ist auch gerade diese Durchlässigkeit am deutlichsten vorhanden, wenn auch, im Gegensatz hierzu, vor allem in den Nachtstunden. Angedeutet finden wir sie auch am 7. während einer und am 11. während 2 Stunden.

Die Radioaktivität der Luft. Diese Messungen hatte Herr Dr. Schäfer aus Rio de Janeiro gütigst übernommen. Am 7. Oktober vormittags wurde der bekannte Elster und Geitelsche Wert A (für 3 Minuten) nach Beendigung der Exposition bestimmt. Der 10 m lange Bleidraht wurde mittelst Hochspannungsbatterie (Günther und Tegetmeyer) auf rund -3000 Volt 2 Stunden lang gehalten. A war gleich 124. Da hierdurch festgestellt wurde, dass die Aktivität in Boå Vista eine recht hohe war, und da es während der Finsternis darauf ankam, möglichst mehrere (relative) Werte zum Vergleich ihres ev. Einflusses zu erhalten, so wurde als Expositionszeit nur $1/4$ Stunde angenommen und der Draht auf 5 m zwecks schnelleren Aufrollens gekürzt. Die Spannung blieb die gleiche von -3000. Es wurde auf diese Weise A (2 Min.) zweimal täglich im Garten zwischen 10a–11a und 4p–5p am 8., 9. und 11. Oktober bestimmt. Die Werte sind ziemlich gleiche, nämlich (zeitlich geordnet): A = 28, 32, 36, 27, 40, 32, d. h. ziemlich hohe. Irgend ein äusserer Einfluss ist bei dieser geringen Zahl von Beobachtungen natürlich nicht zu erkennen. Das mittlere A (2 Minuten) war also nach 10 Min. Exposition des Drahtes gleich 32.

Das Potentialgefälle. Am 3. Oktober wurden die Vorbereitungen für die Aufstellung des registrierenden Quadranten-Elektrometers getroffen; am 4. sollten die Aufzeichnungen beginnen, doch gelang

es erst vom 5. morgens (10a) ab, völlige Isolation zu erzielen. Isolationsprüfungen wurden während des Tages alle zwei — drei Stunden vorgenommen. Am 7. ergab eine Isolationsprüfung um $5^h\ 30^m$a ein ausgezeichnetes Resultat, eine um 9a aber zweifelhafte Ergebnisse. Es werden daher die Werte von 5a bis Mittag, wo der Isolationsfehler behoben wurde, nicht publiziert. Eine letzte gute Isolation wurde am 10. um $8^h\ 30^m$p festgestellt, dann trat ein Versagen ein, das nicht wieder behoben werden konnte. Das feuchte Wetter machte sich eben sehr ungünstig bemerkbar, und das Beobachtungshäuschen war schlecht gebaut. Eine geeignete Heizeinrichtung, die uns einzig und allein unter diesen Umständen genutzt hätte, war leider nicht vorhanden.

Der Kollektor war an einem im Hof befindlichen Pfahl aufgehisst und zwar in 2.50 m Höhe über dem Boden; wir arbeiteten mit 2 Minuten Kontakten der Nadel, zwischen denen 1.7 m Zwischenraum lagen, da das Papier sich 5 cm pro Stunde fortbewegte. Die Empfindlichkeit war eine sehr grosse, 1.8 Volt pro 1 mm; beim Ausschwingen der Nadel über ihr Wirkungsbereich trat automatisch starke Verminderung der Empfindlichkeit (durch Ausschaltung von $\frac{5}{6}$ der Quadrantenbatterie) auf 10.8 Volt pro 1 mm ein. Eine Bestimmung des Reduktionsfaktors erfolgte nicht, da ungestörte heitere Tage nicht vorhanden waren. Dieser Wert ist aber wohl nicht sehr verschieden von 1 anzunehmen, da unsere Aufstellung sich auf einem ebenen Terrain befand.

Bei dem geringen vorhandenen und obendrein stark gestörten (Rauch, wechselnde Bewölkung, Niederschlag) Beobachtungsmaterial, — es stehen nur drei lückenlose Tage zur Verfügung, — ist es unmöglich, einen Anhalt über den täglichen Gang des Potentials selbst nach Ausgleich $\frac{(a + 2b + c)}{4}$ zu gewinnen. Die in Tabelle 9 aufgeführten Stundenwerte wurden gewonnen durch Addition der 7 Werte von 10 zu 10 Min. (0—60 Min.), dividiert durch 7. Nachts scheinen die vorhandenen Werte im ganzen erheblich niedriger zu sein als am Tage, am Nachmittag zwischen 3p—5p am höchsten. Der 6. Oktober hat ein Tagesmittel von 77 Volt/m, der 8. von 40, der 9. von 8. An diesem Tage treten nachmittags negative Stundenmittel bei einsetzendem Niederschlag auf. Der sich entwickelnde Landregen bei cu-ni Bedeckung und sehr hoher Feuchtigkeit hält danach die Werte der Potentialgefälle auf sehr geringer Höhe. Das mittlere Potentialgefälle, aus *allen* vorhandenen Stundenwerten gebildet, ist 35 Volt/m. Die Höchstwerte, die zur

Beobachtung kamen, waren für +610 Volt/m, für −492 Volt/m. Am 7. Oktober zwischen 5p–6p schlug die Nadel kurz hintereinander zwischen +∞ und −∞ aus, ohne dass übrigens der Gewitterregistrator zu dieser Zeit ein Signal gab.

DIE LEITFAEHIGKEIT (λ), LADUNG (E), IONENGESCHWINDIGKEIT (v) UND DER VERTIKALE LEITUNGSSTROM (I).

War die Einrichtung des Quadrantenelektrometers zur Registrierung der luftelektrischen Spannung mit Schwierigkeiten verknüpft, so war sie wenigstens von einigem Erfolg gekrönt, besonders da während der Dauer der Finsternis der Verlauf des Potentials als Registrierung erhalten wurde. Die Aufstellung des Benndorf zur Aufzeichnung der Leitfähigkeit wurde jedoch geradezu zu einem Kreuz unserer Expedition. Bei den Vorversuchen in Santiago unter allerdings günstigsten Bedingungen hatte der Apparat ohne grosse Mühe beste Resultate ergeben. Bei der Witterung, die an unserem Aufenthaltsort in Brasilien herrschte, und der in dieser Hinsicht relativ ungünstigen Oertlichkeit, war alle Arbeit, die wir in Gemeinschaft mit dem Institutsmechaniker Herrn Trollund an die Einrichtung des Elektrometers setzten, vergeblich. Obwohl wir Tag und Nacht kaum ruhten, ja unsere übrigen Obliegenheiten vernachlässigten, gelang es uns nicht, eine befriedigende Isolation zu erzielen. Wir glauben, dass das Benndorfsche Quadrantenelektrometer als Reiseregistrierinstrument für feuchte Gegenden nicht zu empfehlen ist; oder aber man müsste sich der Mühe unterziehen, ein transportables Häuschen mitzunehmen und vor allem eine geeignete Heizvorrichtung, die neben den übrigen Trockenmitteln vielleicht gute Resultate geben würde. Natürlich treten hierbei andere Uebelstände auf (ev. Flammenionen), auf die gebührend Rücksicht zu nehmen wäre.[19]

Für uns wurde es in jedem Fall zwingende Notwendigkeit, direkte Beobachtungen der Leitfähigkeit (λ) anzustellen. Hierzu standen uns bei dem vorhandenen Instrumentarium zwei Wege offen. Erstens konnten wir mit dem Ebertschen Aspirationsapparat Ionendichte und -Geschwindigkeit, letztere unter Benutzung des Vorschaltkondensators, bestimmen und hieraus die Leitfähigkeit berechnen, oder aber wir beobachteten die Leitfähigkeit mittelst des Wulfschen Elektroskops und Zerstreuungscylinder, bei genügendem Schutz gegen das Erdfeld und niedriger Anfangsladung, um freien Strom zu haben.[20]

[19] S. LUEDELING, l. c. 6, S. 43.

[20] S. G. BERNDT, Luftelektrische Beobachtungen in Argentinien, S. 23 in Veröffl. d. *Deutsch. Wissensch. Vereins* in Buenos Ayres No. 3.

Die Ebertsche Methode wurde gerade in Hinblick auf die Sonnenfinsternis nicht benutzt, da sie viel zu lange dauert und daher bei raschem Wechsel der Komponenten, aus denen sich λ zusammensetzt, keine einwandsfreien Resultate liefert. Andererseits konnten auf diese Weise die Leitfähigkeit (λ) und Ladung (E) nicht, wie wünschenswert, synchron beobachtet werden. Es wurde von uns also die oben angedeutete zweite Methode benutzt. Die Länge des Cylinders betrug 30 cm bei 0.5 cm Durchmesser. Wegen Mangels eines Gerdienschen, die Leitfähigkeit direkt messenden Apparates konnte leider keine Reduktion unserer λ Bestimmungen auf dieses Instrument ausgeführt werden. Die von uns mitgeteilten Werte sind daher wohl etwas zu gross, da Berndt bei seinen Vergleichen einen mittleren Faktor 0.84 (Extreme 0.69 und 0.96) fand, mit denen die am Wulf erhaltenen λ zu multiplizieren waren.

Für die Leitfähigkeitsbeobachtungen sowie für die Ablesungen am Ebertschen Aspirationsapparat wurde im Garten ein kräftiger langer Tisch auf einem freien, von der Sonne zu jeder Tageszeit beschienenen Platze aufgestellt, der, um einen guten Schutz gegen das Erdfeld zu bieten, von einem grossen Drahtkäfig[21], in dem die Beobachter bequem Platz fanden, umgeben wurde. Ein Sonnensegel gab den Apparaten und Beobachtern gerade genügenden Schutz gegen direkte Besonnung. Nur dies war nötig; ein breiter Schattenraum zu den Messungen wurde nicht gewünscht, da wir es für annehmbar hielten, dass die Finsternis auf die luftelektrischen Vorgänge einen streng lokalen Effekt äussern könnte, der ev. an einem der Sonne zugänglichen Platze am deutlichsten in Erscheinung treten musste, besonders wenn man an eine Möglichkeit schnell vorübergehender Photowirkungen dachte. Ein zweiter Beobachtungsort, der bei Niederschlägen benutzt werden sollte, befand sich im ersten Stock des Facenda-Gebäudes, wo ein gedeckter breiter, luftiger Gang mit zwei grossen Doppelfenstern, unter denen die Apparate aufgestellt werden konnten, günstige Bedingungen bot.

Die Werte von λ und E wurden von uns, wenn irgend wie möglich, synchron gemessen, und zwar bestimmte je einer von uns die positiven resp. negativen Werte.

Die spezifischen Ionengeschwindigkeiten v wurden aus der Leitfähigkeit und Ladung berechnet (Millicansche Zahl 4.65). Ausser den direkten Beobachtungen, resp. den Ableitungen hieraus, wurden noch andere Werte in Betracht genommen, welche Kombinationen aufeinanderfolgender Beobachtungen (resp. deren Ableitungen),

[21] Der Käfig wurde aus Drahtnetzen, wie sie zur Umzäunung von Gärten dienen, bequem und relativ billig hergestellt.

wenn diese zeitlich nicht zu weit auseinanderlagen, darstellen. Wenn auch eine Reihe luftelektrischer Beobachtungen zwischen dem 3. und 11. Oktober vorgenommen wurden, so musste von einer Diskussion derselben trotzdem Abstand genommen werden, da, abgesehen davon, dass am 10. und 11. Oktober Niederschlag fiel, die an den übrigen Tagen vorhandenen Wirkungen der zahlreichen grösseren und kleineren, nahen und entfernten, zum Zwecke der Rodung und Düngung angezündeten Feuer sicher Störungen und wahrscheinlich häufige rasche Aenderungen der Werte und Unregelmässigkeiten verursachten.

Obwohl im allgemeinen Windstille herrschte, so werden kaum merkbare Luftströmungen für den Transport der aus der Verbrennung herrührenden Substanzen von Bedeutung sein. Bei dieser haben wir wohl zwei verschiedene Produkte zu unterscheiden, einmal gasförmige und zweitens feste und flüssige, letztere als Kondensationsprodukte. Während die Flammenionen, insofern sie nicht als Kondensationskerne dienen, und so zu langsamen Ionen umgewandelt werden, eine Erhöhung der Ionendichte zur Folge haben, werden die anderen Produkte als Dunst, resp. Haarrauch, bei der geringen Geschwindigkeit der sie bildenden Ionen und durch Bindung der leichter beweglichen eine Erniedrigung der Ladung der Luft, resp. der Leitfähigkeit, bewirken. Es war nun auffallend, dass am Tage, besonders in den ersten Nachmittagsstunden, vermutlich bedingt durch die vertikale Luftbewegung, die Sicht durch die Brandpartikel meist (nicht immer) stark getrübt war, während schon in den späten Nachmittags-, sicher aber in den ersten Abendstunden, vielleicht als Folge der Abkühlung, ein völliges Aufklären bei hervorragender Fernsicht eintrat; die Feuersäulen, vorher im Dunst verborgen, wurden weithin sichtbar, und ihre Wirkung am Beobachtungsort verriet sich durch einen öfters auftretenden leichten Brandgeruch. Mit diesem Umstand hängt es möglicherweise zusammen, dass gerade abends die hohen Ionendichten auftraten, indem die schweren Ionen aus der Luft verschwanden.

Zur Uebersicht und zum Vergleich mit den Beobachtungen am Finsternistage seien in der folgenden Tabelle 10 die *Mittel- und Extremwerte der luftelektrischen Beobachtungen mitgeteilt.* Es bedeutet: E_+ und E_- die positive resp. negative Ladung in ESE/m³, n die Zahl der Ionen im cm³, $U = E_+ - E_-$ den Ladungsüberschuss, $Q = \frac{E_+}{E_-}$ den Unipolaritätsquotienten der Ladung, v_+ und

v_- die positiven resp. negativen Ionengeschwindigkeiten in $\frac{\text{cm}}{\text{v}}\frac{\text{sec,}}{\text{cm}}$ $r = \frac{v_-}{v_+}$ ihren Unipolaritätsquotienten, λ_-, λ_-, $\lambda = \lambda_+ + \lambda_-$ die positive, negative und Gesamtleitfähigkeit in ESE, $q = \lambda_+$ die Unipolarität der Leitfähigkeit. Die eingeklammerten Werte entsprechen der Zahl der Beobachtungen resp. Ableitungen aus den Beobachtungen. Die Werte ohne Index (*) sind als Ergebnisse der Einzelberechnungen, die mit dem Index als solche aus den Gesamtmitteln erhalten.

TABELLE 10.—*Mittel- und Extremwerte der Luftelektrischen Elemente in Boã Vista,* 3.—11. *Oktober* 1912.

	Mittel	Max.	Datum	Zeit (h m)	Min.	Datum	Zeit (h m)
E_+	0.49 (112)	1.87	Okt. 11	9 45p	0.10	Okt. 10	10 12a
E_-	0.36 (116)	1.24	" 4	7 55p	0.09	" 10	10 12a
n_+	1054 (112)	4021	" 11	9 45p	215	" 10	10 12a
n_-	774 (116)	2667	" 4	7 55p	193	" 11	10 12a
n	1783 (110); n^*, 1828	5590	" 4	8 10p	408	" 10	10 12a
Q	1.58 (110); Q^*, 1.36	5.58	" 11	9 35p	0.39	" 10	10 18a; 3 17p
U	0.16 (110); U^*, 0.25	1.29	" 4	5 30p	−0.28	" 10	3 07p
v_+	0.58 (102); v_+^*, 0.53	2.00	Okt. 8	9 48a	0.11	Okt. 7	7 45p
v_-	0.71 (108); v_-^*, 0.77	1.71	" 10	11 31a	0.07	" 10	10 21a
r	1.41 (74); r^*, 1.45	4.61	" 10	7 08p	0.13	" 10	10 15a
λ_+	0.78 x 10^{-4} (84)	1.99	Okt. 4	11 26a	0.25	Okt. 10	10 18a
λ_-	0.83 x 10^{-4} (85)	1.89	" 6	9 12p	0.09	" 10	10 12a; 10 39a
λ	1.54 x 10^{-4} (99)	3.57	" 6	9 12p	0.34	" 10	10 10a
λ^*	1.61 x 10^{-4}	...	...	...	...	...	...
q	0.99 (99); q^*, 0.94	3.33	" 10	10 29a	0.57	" 10	5 37p

Betrachten wir nun kurz die Ergebnisse der hier mitgeteilten Resultate (Tabelle 10); schon ein flüchtiger Blick zeigt, dass grosse Störungen vorhanden sein mussten. Die Mittelwerte von E_+ und n_+ sind hohe, die Werte von E_- und n_- ordnen sich hingegen in die sonst gefundenen ein. Infolgedessen haben wir auch hohe Werte von Q und U. Trotzdem entsprechen die Resultate den gelegentlich an anderen Orten gefundenen luftelektrischen Bedingungen, besonders gut z. B. den von Dieckmann in Jachenau[22] erhaltenen. Das Maximum für E_+ ist ziemlich hoch. Im ganzen sind unter 112 Ablesungen 11 Werte von $E_+ > 1$ vorhanden, die alle, mit Ausnahme eines Frühwertes, in den Abendstunden gemessen wurden. Entsprechend den grossen Ionendichten, n_+, sind

[22] S. H. EBERT, Ionenzählungen bei Gelegenheit der totalen Sonnenfinsternis am 30. August 1905 in *Phys. Zeitsch.* No. 20 1905, S. 642.

die Maxima für Q und U sehr hohe. Die Maxima für E_- und n_-, sowie alle Minima E_+ und n_+, E_- und n_-, Q und U halten sich in den normalen Grenzen. Nur 2 gleichfalls in die Abendstunden fallende Werte von E_- sind (unter 116 Beobachtungen) >1. Die Mittel der specifischen Ionengeschwindigkeiten sind vorzüglich für v_+ niedrige; der Unipolaritätsfaktor ist ein ziemlich hoher. Die Maxima sind sehr hoch, auch für r, die Minima zeigen keine herausfallenden Werte. Die mittleren λ entsprechen, da die kleinen Geschwindigkeiten die grösseren Ladungen kompensieren, den auch sonst gefundenen Leitfähigkeiten. Die Extremwerte sind gleichfalls normale.

Der *vertikale Leitungsstrom* zeigt entsprechend dem niedrigsten Potentialgefälle sehr kleine Werte. Wir erhalten im Mittel: $I_+ = 0.25$, $I_+{}^* = 0.31$; $I_- = 0.34$, $I_-{}^* = 0.32$; und $I = 0.46$, $I^* = 0.65 \times 10^{-16}$ Amp cm^2. Die Extremwerte sind: $I_+ = 1.23$ (6. Okt. $9^h\ 12^m$p), resp. 0.00 (öfters); für $I_- = 4.66$ (6. Okt. $2^h\ 45^m$p), resp. 0.00 (öfters); und $I = 4.78$ (6. Okt. $2^h\ 40^m$p) $\times 10^{-16}$ Amp cm^2, resp. 0.00 (öfters).

Luftelektrische Beobachtungen in Boã Vista am Finsternistage, 10. Oktober 1912.

Hertzsche Wellen. Die Finsternis liess keinen Einfluss auf den Gewitterregistrierapparat erkennen, im Gegensatz zu den Beobachtungen Cireras[23] zu Tortosa im Jahre 1905. Wie auch an anderen Tagen wurden einige Wellen am Vormittage, also auch zur Zeit der Bedeckung, aufgenommen.

Die Radioaktivität der Luft. Wir hielten es für wichtig, einige wenigstens relative Messungen über den Gehalt der Atmosphäre an aktiven Induktionen während der Bedeckung vorzunehmen, einmal wegen des Interesses an sich, ferner wegen des ev. Einflusses einer Aenderung des Emanationsgehaltes auf die luftelektrischen Werte. Hierbei ist kaum an die Wirkung einer an sich nur geringen ev. durch die Finsternis bedingten Luftdruckschwankung auf den Gehalt an Emanation zu denken, sondern vielmehr an die der Abkühlung. Theoretisch wäre anzunehmen, dass eine Abnahme der Aktivität und damit eine Minderung der Ionisierung nach der Totalität eintreten würde. Das am Finsternistage herrschende Wetter verhinderte uns, den Beweis für unsere Annahme zu führen, da nur bei heiterem Himmel eine genügende Abkühlung der äusseren Bodenschichten zur Erzielung des Effekts zu erwarten war.

[23] S. R. Cirera, l. c. 5, S. 37.

Wir erhielten die folgenden Werte von *A* (2 Min), die keinen Einfluss der Finsternis erkennen lassen (s. Tabelle 11). Die Zeiten beziehen sich auf die Expositionsdauer.

TABELLE 11.—*Werte der Aktivität* (*A*) *am* 10. *Oktober* 1912.

Zeit	*A*	Zeit	*A*	Zeit	*A*
h m h m		h m h m		h m h m	
8 00–8 15a	19	10 00–10 15a	22	Mittag–12 15p	19
8 30–8 45a	23	10 30–10 45a	20	12 30–12 45p	18
9 00–9 15a	18	11 00–11 15a	24	1 00– 1 15p	20
9 30–9 45a	20	11 30–11 45a	21		

Der mittlere Wert von A hieraus, 20, ist kleiner als der an den Vortagen erhaltene, ein Umstand, der wahrscheinlich auf die Durchfeuchtung des Bodens zurückzuführen ist.

Das Potentialgefälle. Die dem Registrierapparat entnommenen Werte des Potentials (Volt/m) von 5 zu 5 Min enthält die folgende Tabelle 12.

TABELLE 12.—*Potentialgefälle während der Sonnenfinsternis in Boã Vista am 10. Oktober 1912.*

Zeit	Pot.	Zeit	Pot.	Zeit	Pot.	Zeit	Pot.	Zeit	Pot.	Zeit	Pot.	Zeit	Pot.
h m		h m		h m		h m		h m		h m		h m	
7 45	7	8 35	2	9 20	2	10 05	8	10 50	6	11 35	10	12 20	4
50	7	40	0	25	4	10	5	55	7	40	7	25	3
55	5	45	6	30	0	15	5	11 00	8	45	8	30	5
8 00	6	50	7	35	−3	20	4	05	7	50	5	35	6
05	6	55	7	40	0	25	4	10	6	55	7	40	7
10	6	9 00	8	45	8	30	2	15	7	12 00	4	45	9
15	5	05	9	50	12	35	3	20	5	05	8	50	10
20	4	10	8	55	3	40	5	25	8	10	9	55	8
25	3	15	8	10 00	8	45	8	30	10	15	5	1 00	5
30	4												

Während der Finsternis blieb der Wert des Potentialgefälles sehr klein, zwischen −3 und 12 schwankend, und im Mittel gleich dem des (allerdings nicht vollständig registrierten) 10. Oktober überhaupt, nämlich 6. Die Ursachen für die Kleinheit der Werte wurden schon oben angegeben. Der Verlauf war wie während des ganzen Tages ein ziemlich ruhiger, mit Ausnahme des Intervalls 9–10a. Um zu untersuchen, ob etwa eine wenn auch absolut nur kleine Einwirkung der Bedeckung stattfand, bildeten wir die Mittel aus

5 Stundenintervallen, nämlich für $7^h\ 45^{ma}-8^h\ 45^{ma}$, d. i. die Periode vor dem Ereignis, $8^h\ 45^{ma}-9^h\ 45^{ma}$ die der zunehmenden, $9^h\ 45^{ma}-10^h\ 45^{ma}$ die der grössten, $10^h\ 45^{ma}-11^h\ 45^{ma}$ die der abnehmenden Bedeckung und $11^h\ 45^{ma}-12^h\ 45^{mp}$ die Periode nach der Finsternis. Wir erhalten resp. die folgenden 5 Werte: 5, 5, 6, 7, 6. Die Werte bleiben also völlig konstant, und ein *Einfluss der Finsternis auf das Gefälle wäre danach nicht vorhanden.* Auch aus den Einzelwerten (resp. der graphischen Darstellung) ist ein solcher kaum zu entnehmen. Die auftretenden absolut sehr kleinen Schwankungen (Zacken) sind wahrscheinlich durch die Niederschläge resp. kleine Aenderungen der Bewölkung bedingt. Zum Vergleich mit unserem Ergebnis seien die Resultate einiger anderer Beobachtungen des Potentials bei Sonnenfinsternissen mitgeteilt. Ein hinzugefügtes Fragezeichen (?) deutet an, dass die Witterungsverhältnisse während der Beobachtung ungünstige waren.

Bei der Sonnenfinsternis in Wolfenbüttel (19. Aug. 1887) wurde ein Sinken des Gefälles von Elster und Geitel[24] (?) beobachtet, das Gleiche von Ludewig[25] (22. Jan. 1898) in Südindien. Elster[26] stellte bei der totalen Sonnenfinsternis in Algier (28. Juni 1900) gleichfalls ein Minimum des Gefälles kurz nach der Totalität fest. Bei der totalen Sonnenfinsternis d. 30. August 1905 beobachtete Gockel[27] (?) in Vinaros (Spanien) unmittelbar während der Totalität ein Steigen, zur selben Zeit ein Gleiches Nordmann[28] in Philippeville (Algerien). Keinen Gang des Potentials, das an sich einen geringen Betrag zeigte, erhielt Ebert[29] (?) in Palma de Mallorca, während nach *Elster und Geitel*[30] (?) am gleichen Ort bei ziemlich stark schwankendem Verlauf mit Ablauf der Totalität eine Schwächung mit darauf folgender Zunahme des Gefälles stattfand. Ein ähnliches Verhalten, aber 12 Min. nach der Totalität, fand Le Cadet[31] (?) in Tortosa-(Roquetas). Hier, am Ebro Observatorium, beobachtete Cirera[32] (?) unter kleinen Schwankungen 5 Min. vor der Totalität eine Minderung und während derselben eine Periode völliger Ruhe des Erdfeldes. Schliesslich arbeitete am 30. August 1905 in Spanien, in Burgos, die Expedition des Kgl. Preuss. Meteorol. Instituts unter Lüdeling[33]

[24] S. *Met. Zeitschr.* 1888, No. 5, S. 27.

[25] S. cit. Brommer, Luftelektr. Messungen während d. part. Sonnenfinsternis am 17. April 1912. A. d. *Sitzungsber. d. k. Akademie d. Wissenschaften* in Wien. Mathem.-naturw. Klasse; Bd. (XX). Abt. 11. Juni 1912.

[26] S. *Phys. Zeitschr.* 1901, No. 2, S. 66.

[27] S. *Phys. Zeitschr.* 1905, No. 19, S. 617. [28] S. *Compt. rend.* 1905, 142, S. 40.

[29] S. *Phys. Zeitschr.* 1905, No. 6, S. 641. [30] S. *Terr. Mag. and Atm. Elec.* 1906, S. 1-44.

[31] S. *Compt. rend.* 1905, 141, S. 925. [32] S. l. c. 5, S. 36. [33] S. l. c. 6, S. 34.

(?) und mass bei niedrigem Stande und beginnend 40 Min. vor dem 2. Kontakt langsam abnehmende Werte, die bei Beginn der Totalität wieder in langsames Steigen übergingen und den normalen Stand 15 Min. vor Schluss der Finsternis erreichten. — Anschliessend seien auch noch die Ergebnisse der partiellen Sonnenfinsternis vom 17. April 1912 betrachtet. Süring[34] (?) fand in Potsdam keine Einwirkung der Finsternis auf das Potential, Budig[35] auf dem Brocken zur Zeit des Finsternismaximums eine Depression, hingegen Bergwitz[36] in dem benachbarten Braunschweig eine Zunahme. Keine Besonderheiten zeigte die Gefällskurve nach Dobson[37] (bei ziemlich hohem Stande) in Kew.

Zusammenfassend kann man wohl sagen, dass bisher die Frage über das *Verhalten des Erdfeldes bei Sonnenfinsternissen*, trotz einer grösseren Reihe von Beobachtungen, die allerdings zumeist wegen der Witterung wenig einwandsfrei waren, *nicht beantwortet ist.* Da aber bei dem gleichen Ereignis und oft am gleichen Ort, bald tiefer, bald hoher Stand, bald Fallen oder Steigen, und obendrein in verschiedenen Phasen der Finsternis, bald auch Gleich- resp. Unbeeinflusstbleiben, schwankender oder ruhiger Verlauf des Gefälles beobachtet wurden, möchte man fast zu der Annahme neigen, dass *eine Beeinflussung des Potentials durch die Bedeckung der Sonne nicht stattfindet.*

Die Leitfähigkeit (λ), *Ladung* (E), *Ionengeschwindigkeit* (v) *und der Vertikale Leitungsstrom* (I). Während der Sonnenfinsternis, sowie einer Vor- und Nachperiode, d. h. zwischen 8a und 1p, wurden im ganzen gemessen 28 E_+, 33 E_-, 16 λ_+ und 18 λ_-, indem der eine von uns die negativen, der andere die positiven Beobachtungen ausführte; dieser hatte zudem die Zeitangaben zu machen und auf die äusseren Vorgänge zu achten. Es kommt also auf E_+, E_-, λ_+, λ_- je eine Beobachtung auf resp. 11, 9, 19 und 17 Min. Durch Berechnung konnten die übrigen luftelektrischen Werte gewonnen werden, der vertikale Leitungsstrom unter Zuhilfenahme des dem Registrierapparate entnommenen Potentials. Die Werte für E_+, E_- sind synchrone; die Beobachtungen der Leitfähigkeit konnten aus Zeitmangel nur umschichtig ausgeführt werden, so dass sie zwar etwa mit den Bestimmungen der Ladung zusammenfallen, aber nicht untereinander gleichzeitig sind. Wir hätten natürlich auch hier die Ablesungen synchron gestalten können, doch wären dann die Ableitungen, die Gesamtleitfähigkeit und die Unipolarität q zeitlich sehr auseinandergefallen. Wir haben es

[34] S. *Met. Zeitschr.* 1912, No. 29, S. 440.
[35] S. l. c. 3, S. 84.
[36] S. *Phys. Zeitschr.* 1912, No. 13, S. 767.
[37] S. l. c. 7, S. 227.

daher vorgezogen, die letzteren Werte weniger genau, aber fast in doppelter Zahl zu erhalten.

Die folgende Tabelle 13 mag zunächst in grossen Zügen zeigen, ob ein Einfluss der Finsternis auf die luftelektrischen Verhältnisse der Atmosphäre anzunehmen ist, indem die Tagesmittel des 10. Oktober 1912, dieselben unter Ausschluss der Finsternis ($8^{h}\ 54^{m}$ bis $11^{h}\ 41^{m}$), die Mittel aus den zwischen dem 1. und 4. Kontakt gewonnenen Werten, sowie die Mittel der einzelnen Stunden-, nach der Finsternis zwei Stundenintervalle, mitgeteilt werden.

Zunächst ist aus der Tabelle ersichtlich, dass die Mittel des Finsternistages aller luftelektrischen Werte, mit Ausnahme der negativen Ladung E_{-} und der Unipolarität der spec. Ionengeschwindigkeiten r, die keine Aenderung zeigen, eine teilweise beträchtliche Verkleinerung gegenüber den Gesamtmitteln (s. Tab. 10) zeigen. Diese Verkleinerung ist aber zunächst nicht der Finsternis, sondern der von den anderen Tagen so abweichenden Witterung des 10. Oktober zuzuschreiben, da auch die luftelektrischen Mittelwerte dieses Tages, unter Ausschluss der während der Bedeckung erhaltenen Resultate, eine ähnliche Verkleinerung gegenüber den Gesamtmitteln zeigen. Vergleichen wir aber die Mittel der während des 1. und 4. Kontakt angeführten Beobachtungen, resp. die ihrer Ableitungen, mit den ausserhalb der Finsternis am gleichen Tage erhaltenen, so scheint der Einfluss des Phänomens bei einzelnen Elementen bereits deutlich zu werden. Die Finsternis bewirkte wahrscheinlich eine leichte Verringerung der Ionenzahl, eine beträchtliche Minderung der Geschwindigkeiten der $-$Ionen und damit eine Abnahme der entsprechenden Unipolarität, im Zusammenhang hiermit eine Verkleinerung der negativen und Gesamtleitfähigkeit, sowie eine Erhöhung ihrer Unipolarität.

Noch deutlicher und fast beweisend wird die Wirkung der Sonnenbedeckung auf die Werte bei Betrachtung der Stundenintervalle. Es giebt danach kaum ein Element, das nicht beeinflusst worden wäre; nur die Aenderungen des vertikalen Leitungsstromes sind, wegen ihrer Geringfügigkeit (ev. Erhöhung seiner positiven Komponente im Stundenintervall der abnehmenden Verfinsterung, ev. Verminderung der negativen Komponente und des Gesamtleitungsstromes im Intervall der Totalität) zweifelhaft. Eine sehr deutliche Abnahme zeigen während des Stundenintervalls, das die Totalität einschliesst, die positive Ladung E_{+}, die auch im Mittel der folgenden Stunde sehr klein bleibt; etwas geringere

TABELLE 13.—*Werte der Luftelektrischen Elemente in Boa Vista am Finsternistage und während der Finsternis.*

Nr.	Zeit	E_+	E_-	n	u	Q	v_+	v_-	r	λ_+ 10^4 x	λ_- 10^4 x	λ 10^4 x	q	I_+ 10^{16} x	I_- 10^{16} x	I 10^{16} x
	h m — h m															
I	8 00—22 22	.37 (43)	.34 (40)	1426 (46)	.06 (46)	1.36 (46)	.49 (50)	.58 (60)	1.49 (35)	.43 (24)	.53 (26)	0.92 (38)	1.06 (38)	.02 (23)	.03 (24)	.05 (31)
II	8 00—22 22	.37 (20)	.35 (25)	1467 (20)	.06 (20)	1.32 (20)	.49 (23)	.64 (31)	1.65 (14)	.44 (14)	.63 (14)	1.08 (18)	0.74 (18)	.02 (12)	.03 (12)	.04 (17)
III	8 55—11 38	.36 (23)	.32 (21)	1394 (26)	.06 (26)	1.38 (26)	.49 (27)	.50 (29)	1.38 (21)	.40 (10)	.41 (12)	0.78 (20)	1.35 (20)	.03 (11)	.03 (12)	.05 (20)
IV	7 45— 8 45	. . .	.44 (6)				. . .	.58 (7)	. . .	.63 (2)	.67 (3)	1.35 (3)	0.89 (3)	.02 (2)	.01 (3)	.01 (3)
V	8 45— 9 45	.58 (6)	.47 (7)	2264 (6)	.09 (6)	1.23 (6)	.26 (4)	.35 (10)	1.68 (4)	.45 (3)	.48 (4)	0.99 (5)	0.91 (5)	.02 (3)	.04 (4)	.05 (5)
VI	9 45—10 45	.25 (9)	.28 (8)	1154 (9)	−.02 (9)	0.95 (9)	.50 (14)	.32 (11)	0.77 (9)	.31 (5)	.24 (4)	0.57 (9)	1.91 (9)	.02 (5)	.00 (4)	.03 (9)
VII	10 45—11 45	.29 (9)	.22 (8)	1104 (12)	.09 (12)	1.69 (12)	.69 (10)	.82 (12)	1.77 (9)	.50 (4)	.57 (5)	1.01 (9)	0.88 (9)	.04 (4)	.05 (5)	.08 (9)
VIII	11 45—12 45	.46 (3)	.26 (3)	1563 (3)	.19 (3)	1.74 (3)	.65 (4)	.91 (3)	1.44 (2)	.49 (2)	.63 (1)	1.21 (2)	0.68 (2)	.03 (2)	.03 (1)	.07 (2)
IX	13 00—18 16	.35 (12)	.35 (11)	1504 (12)	.01 (12)	1.12 (12)	.38 (15)	.56 (14)	1.45 (9)	.36 (6)	.54 (6)	0.88 (8)	0.67 (8)	.02 (6)	.03 (6)	.04 (8)
X	19 04—22 22	.42 (4)	.25 (3)	1414 (4)	.19 (4)	1.86 (4)	.45 (3)	.97 (3)	3.30 (2)	.50 (2)	.73 (3)	1.18 (2)	0.73 (2)	.02 (1)	.03 (1)	.05 (1)

Nr.	Zeit	n*	u*	Q*	v_+*	v_-*	r*	λ* 10^4 x	q*	I_+* 10^{16} x	I_-* 10^{16} x	I* 10^{16} x	Bemerkungen
	h m — h m												
I	8 00—22 22	1527	.03	1.09	.39	.52	1.33	0.96	0.81	.02	.03	.05	Mittel des Finsternistages.
II	8 00—22 22	1548	.02	1.06	.40	.60	1.50	0.93	0.70	.02	.04	.06	Mittel des Finsternistages mit Ausschluss der Finsternis.
III	8 55—11 38	1462	.04	1.12	.41	.43	1.05	0.81	0.98	.03	.03	.06	Mittel der Finsternis.
IV	7 45— 8 45					.51		1.30	0.94	.03	.03	.06	Stundenintervall vor der Finsternis.
V	8 45— 9 45	2258	.11	1.23	.26	.34	1.31	0.93	0.94	.02	.02	.04	Stundenintervall der zunehmenden Verfinsterung
VI	9 45—10 45	1140	−.03	0.89	.41	.28	0.68	0.55	1.29	.02	.02	.04	Stundenintervall der Totalität.
VII	10 45—11 45	1097	.07	1.32	.57	.86	1.51	1.07	0.88	.04	.04	.08	Stundenintervall der abnehmenden Verfinsterung.
VIII	11 45—12 45	1548	.20	1.77	.36	.81	2.25	1.12	0.78	.03	.04	.07	Stundenintervall nach der Finsternis.
IX	13 00—18 16	1505	.00	1.00	.34	.51	1.50	0.90	0.67	.02	.02	.04	Mittel am Nachmittag.
X	19 04—22 22	1441	.17	1.60	.40	.97	2.42	1.23	0.68	.03	.05	.08	Mittel am Abend.

* Die Werte ohne Index (*) sind als Ergebnisse aus den Einzelberechnungen, die mit dem Index (*) als solche aus den Gesamtmitteln erhalten.

aber doch beträchtliche Minderung zeigt die negative Ladung E_-, deren Minimum allerdings in die Zeit der abnehmenden Finsternis fällt. Gleichzeitig bemerken wir den geringsten Wert der Ionenzahl n, der auf die Hälfte des während der Zunahme erhaltenen Mittels gesunken ist. Der Ueberschuss U der + Ladung, der im allgemeinen vorhanden ist, verschwindet wegen der relativ stärkeren Abnahme gegenüber der − Ladung während der Totalität und wird sogar negativ; aus diesem Grunde wird die Unipolarität $Q < 1$. Abweichend von den übrigen luftelektrischen Werten zeigt die +Ionengeschwindigkeit v_+ eine Zunahme, die am grössten ist in der Stunde, welche die abnehmende Bedeckung umschliesst. Umgekehrt nimmt die specifische Geschwindigkeit v_- der −Ionen unter dem Einfluss der Verfinsterung schon bei der Bedeckung stark ab und ist während des Totalitätsintervalls am ausgeprägtesten. In Folge dieses ungleichen Verhaltens von v_+ und v_- kehrt sich ihre Unipolarität in dem Intervall, das den 2. und 3. Kontakt einschliesst, völlig um. Da die Abnahme von E_+ relativ stärker ist als die Zunahme von v_+, so zeigt auch die positive Leitfähigkeit λ_+ eine Verminderung (auf die Hälfte); sie ist bei der Leitfähigkeit λ_- viel bedeutender (etwa nur $1/3$ des Stundenmittels vor und nach Beginn der Finsternis), ein Umstand, der sich in dem überaus hohen Quotienten der Unipolarität q ausspricht, der beinahe den Wert 2 erreicht, während die Unipolarität vorher und nachher < 1 ist. Die Gesamtleitfähigkeit zeigt naturgemäss eine starke Abnahme. Alle λ-Werte erreichen das Minimum (resp. q das Maximum) während der Totalität.

Der bei den Mitteln der Stundenintervalle so hervortretende Einfluss der Sonnenfinsternis macht sich, allerdings durch starke Schwankungen der benachbarten Ablesungen bei den meisten luftelektrischen Elementen gestört, auch in ihrem Gange bemerkbar. Betrachten wir daher jetzt die direkten Werte (in dem Zeitraum zwischen 8a und 1p), resp. die (nach $\frac{a + b + c}{3}$) ausgeglichenen Werte, welche zur graphischen Darstellung dienten. (S. Tab. 13 und Fig. 4.)

Die direkten Werte zeigen an (s. auch Tab. 10), dass die absoluten und sehr tiefen Minima der Beobachtungen am Finsternistage (und aller Beobachtungen überhaupt) für die positive und negative Ladung, E_+ und E_-, für die Ionenzahl n, für die Unipolarität Q, für die negative Ionengeschwindigkeit v_-, für den Quotienten der spec. Geschwindigkeiten r, für die positive, negative und Gesamt-

leitfähigkeit, λ_+, λ_-, λ, für den negativen vertikalen Leitungsstrom I_-, in die Zeit der Finsternis, und zwar in die Zeit der grössten Bedeckung, resp. die Minuten danach fallen; bei Q tritt ein ebenso tiefes Minimum allerdings am Nachmittage des 10. Oktober auf, für I_- auch am 8. Oktober. Ein absolutes, sehr ausgeprägtes Maximum zeigt gegen Ende der Bedeckung die $-$ Ionengeschwindigkeit v_-, deren absolute Extreme also innerhalb des ersten und vierten Kontaktes liegen, sowie einige Minuten nach der Totalität die Unipolarität der Leitfähigkeit q. Unter allen beobachteten resp. abgeleiteten luftelektrischen Elementen zeigen so nur der positive und gesamte verticale Leitungsstrom, I_+ und I, keine absoluten Extremwerte während der Sonnenfinsternis.

Ueber den *allgemeinen Verlauf der einzelnen Elemente* ist Folgendes zu bemerken. (S. Tab. 14, Fig. 4.)[38] Es bedeuten wie bisher: E_+ und E_- die positive resp. negative Ladung in ESE/m^3, n die Zahl der Ionen in cm^3, $v = E_+ - E_-$ den Ladungsüberschuss, $Q = \frac{E_+}{E_-}$ den Unipolaritätsquotienten der Ladung, v_+ und v_- die positiven resp. negativen Ionengeschwindigkeiten in $\frac{\text{cm sec}}{\text{v cm}}$, $r = \frac{v_-}{v_+}$ ihren Unipolaritätsquotienten, λ_+, λ_-, $\lambda = \lambda_+ + \lambda_-$ die positive, negative und Gesamtleitfähigkeit in ESE, $q = \frac{\lambda_+}{\lambda_-}$ die Unipolarität der Leitfähigkeit und I_+, I_-, $I = I_+ + I_-$ den vertikalen Leitungsstrom in Amp/m^2, sowie seine beiden Komponenten. Die kursiv gedruckten Werte entsprechen Interpolationen aus direkt abgeleiteten Werten.

Für E_+ findet vor Beginn der Finsternis bis kurz nach der Totalität ein ziemlich gleichmässiger, beträchtlicher Abfall statt, darauf beginnt ein Ansteigen, das, durch zweites Minimum zur Zeit des vierten Kontaktes unterbrochen, über die Finsternis hinaus anhält. Die Werte von E_- sind im ganzen gleichmässiger. Erst rund drei Viertel Stunden nach dem 1. Kontakt beginnt ein rascher Abfall, der eine Viertelstunde vor der Totalität zum ersten Minimum führt; darauf findet, nach einem leichten Anstieg, von 11 Uhr ab als eine Reihe gleichbleibender niedriger Werte ein bis gegen das Ende der Finsternis andauerndes zweites Minimum statt.

Die Gesamtionenzahl n zeigt eine sehr ausgeprägte Beeinflussung; sie fällt vom Beginn der Bedeckung mit rund 2400 Ionen/cm^3

[38] Man tut bei der Betrachtung der Werte der Tabellen 13 und 14 gut, die Werte auf nur eine Dezimale abzurunden, um die wesentlichen Aenderungen besser verfolgen zu können.

TABELLE 14. — *Ausgeglichene Werte der Luftelektrischen Elemente in Boã Vista während der Finsternis am 10. Oktober 1912.*

N°	Zeit h m	E_+	E_-	n	n^*	Q	Q^*	v_+	v_+^*	v_-	v_-^*	r	r^*	λ_+ $10^4\times$	λ_- $10^4\times$	λ $10^4\times$	λ^* $10^4\times$	q	q^*	I_+ $10^{16}\times$	I_+^* $10^{16}\times$	I_- $10^{16}\times$	I_-^* $10^{16}\times$	I $10^{16}\times$	I^* $10^{16}\times$
1	8 15		50																						
2	8 22		42																						
										0.59	*0.53*														
3	8 32		38							0.69	0.59				0.67							0.02	0.03		
										0.74	*0.60*					1.35	1.26	0.89	0.88					0.04	0.04
4	8 38		37											0.59						0.03	0.01				
										0.63	*0.57*					1.26	1.22	0.88	0.94					0.04	0.03
5	8 43		40							0.55	0.52				0.63							0.02	0.02		
										0.45	*0.48*					1.13	1.13	0.95	0.79					0.05	0.04
6	8 49		44											0.50						0.03	0.02				
										0.42	*0.44*					0.99	0.99	0.85	0.86					0.06	0.06
7	8 55		47							0.38	0.41				0.58							0.04	0.04		
																0.98	1.03	0.84	0.78					0.07	0.08
8	9 03	61	49	2365	2366	1.28	1.24	0.24	0.24					0.45						0.03	0.04				
										0.40	*0.34*	*1.95*	*1.42*												
9	9 13														0.50							0.03	0.04		
										0.37	*0.34*	*1.28*	*1.26*			0.94	0.90	0.90	0.90					0.05	0.06
10	9 20	49	49	2107	2107	1.00	1.00	0.30	.27					0.40						0.03	0.02				
								0.32	*.25*	*0.34*	*0.33*	*1.28*	*1.32*			0.92	0.88	0.96	0.83					0.04	0.02
11	9 29	53	52	2257	2323	1.01	1.03			0.26	0.31				0.48							0.02	0.00		
										0.23	*0.34*														
12	9 33	54	47	2164	2172	1.18	1.15																		
										0.28	*0.31*														
13	9 42	46	41	1870	1873	1.13	1.12			0.37	0.35				0.43							0.00	0.01		
								0.37	*.29*	*0.48*	*0.48*	*1.37*	1.66			0.83	0.83	0.95	0.93					0.03	0.03
14	9 52	35	30	1383	1398	1.16	1.17	0.38	.38					0.40						0.02	0.02				
								0.42	*.44*	*0.53*	*0.43*	*1.56*	0.98			0.82	0.79	0.80	1.03					0.04	0.04
15	10 01	30	22	1248	1118	1.05	1.36			0.72	0.59				0.39							0.01	0.02		
				982	*989*	*1.11*	*1.09*	*0.39*	*.37*			*1.26*	*1.59*			0.78	0.72	0.95	0.85					0.04	0.04
16	10 07	.24						0.68	.46					0.33						0.03	0.02				
								0.82	*.58*			*0.86*	*0.62*			0.68	0.61	0.99	1.18					0.04	0.04
17	10 12	.19	26	960	968	0.86	0.73			0.61	0.36				0.28							0.01	0.02		
								0.86	*.54*	*0.45*	*0.33*	*0.42*	0.61			0.51	0.59	1.66	1.11					0.04	0.04
18	10 18	14	28	910	903	0.65	0.50	0.62	.74					0.31						0.02	0.02				
								0.56	*.54*	*0.13*	*0.18*	*0.23*	0.33			0.42	0.46	2.33	2.07					0.03	0.03
19	10 25	.19	33	1125	1118	0.66	0.58			0.11	0.15				0.15							0.01	0.01		
								0.51	*.49*	*0.14*	*0.18*	*0.28*	0.37			0.37	0.43	3.15	1.87					0.02	0.03

* Die Werte ohne Index (*) sind als Ergebnisse aus den Einzelberechnungen, die mit dem Index (*) als solche aus den Gesamtmitteln erhalten.

TABELLE 14.—*Ausgeglichene Werte der Luftelektrischen Elemente in Boa Vista während der Finsternis am 10. Oktober 1912.*—Fortsetzung.

Nr.	Zeit	E_+	E_-	n	n^*	Q	Q^*	v_+	v_+^*	v_-	v_-^*	r	r^*	λ_+ 10^4 x	λ_- 10^4 x	λ 10^4 x	λ^* 10^4 x	q	q^*	I_+ 10^{16} x	I_+^* 10^{16} x	I_- 10^{16} x	I_-^* 10^{16} x	I 10^{16} x	I^* 10^{16} x
								0 46	.11					0.28						0.02	0 02				
20	10 33	.23	.27	1068	1075	0 91	0.85	*0 37*	*.28*	*0 16*	*0.23*	*0 31*	0.82			0.38	0 47	3 26	1 47					0.03	0 03
										0.13	0 23				0 19							0 01	0 01		
21	10 39	.33	.28	1305	1312	1 16	1 18	*0 31*	*31*	*0 19*	*0.21*	*0.46*	0.68			0.48	0 50	2.37	1.63					0 04	0 03
								0 35	.34					0.31						0 02	0 02				
22	10 43	30	30	1297	1290	1.00	1 00	*0 15*	35	*0 30*	*0 35*	*0 70*	*1 00*			0 60	0 61	1 56	1.03					0 04	0 04
										0 50	0 34				0 30							0 03	0 02		
23	10 49	31	29	1276	1290	1 09	1 07	*0 53*	*36*	*0 68*	*0 48*	*1.91*	1 33			0 73	0 63	0.82	1 10					0 05	0 04
								0 44	34					0 33						0 02	0 02				
24	10 59	.32	21	1139	1140	1 80	1 5[illegible]	*0 35*	*30*																
25	11 04	37	16	1139	1140	2 32	2 31			*0 82*	*0 92*	2 60	3 07			0.76	0 77	0 89	0 75					0 06	0 05
				1151	*1204*	*2 58*	*2 58*								0 44							0 04	0 03		
26	11 09	40								*0 98*	*0 77*	3.42	1 67			0 80	0 90	0.84	1 04					0 06	0 07
				1068	*1269*	*2 31*	*2 10*							0 46						0 03	0 04				
27	11 18	33	19	1039	1118	2 22	1 74	0 43	46	*0 88*	*0 96*	2 41	2 09			0 94	1 01	0 95	0 84					0 08	0.08
				1168	*1118*	*2 03*	*1 74*								0 55							0 06	0 04		
28	11 22									*0 87*	*0 96*	1 91	1 68			1 14	1 11	0 95	1 02					0 11	0 10
				1197	*1118*	*1 54*	*1 74*	0 58	57					0 56						0 04	0 06				
29	11 26	33	19	1214	1118	1 66	1 74	*0 70*	*69*	*1 06*	*1 19*	1 11	1 72			1 30	1 24	1 02	0 82					0 14	0 13
										1 13	0 91				0 68							0 07	0 07		
30	11 31	.27	24	1099	1097	1 35	1 12	*0 79*	*76*	*1 10*	*0 91*	1 02	1 20			1 40	1 30	0 87	0 91					0 14	0 13
								1 12	94					0 62						0 05	0 06				
31	11 38	22	25	1014	1010	1 1[illegible]	0 88	*1 30*	*74*	*0 87*	*0 96*	0 85	1 30			1 40	1 34	0 80	0 86					0 12	0 12
										1 00	0 86				0 72							0 06	0 06		
32	11 44	28	28	1204	1204	1 06	1 06	*1 17*	*66*	*0 94*	*0 86*	1 19	1 30			1 3[illegible]	1 27	0 72	0 76					0 09	0 09
								0 75	50					0 55						0 04	0 03				
33	11 52	37	28	1398	1398	1 40	1 32	*0 38*	*40*	*0 91*	*0 80*	1 47	2 00												
										0 77	0 83				0 67							0 04	0 04		
34	12 27	40	27	1563	1570	1 71	1 70									1 13	1 14	0 70	0 70					0 07	0 07
								0 41	40					0 17						0 03	0 03				
35	12 31	39	31	1513	1505	1 3[illegible]	1 25	*0 45*	*44*	*0 60*	*0 61*	1 54	1 45												
										0 58	0 53				0 60							0 03	0 03		
36	1 00	36	38	1584	1591	0 99	0 95	*0 40*	*35*	0 18	*0 14*	1 16	1 26			1 01	0 98	0 69	0 63					0 05	0 05
														0 38						0 02	0 02				
37	1 49	33	45	1670	1677	0 75	0 73	0 42	38																

* Die Werte ohne Index (*) sind als Ergebnisse aus den Einzelberechnungen, die mit dem Index (*) als solche aus den Gesamtmitteln erhalten.

auf etwa 900 zur Zeit des dritten Kontaktes; nach raschen Aenderungen bei relativ kleinen Werten (1000—1300) steigen die Werte erst nach dem vierten Kontakt ziemlich allmählich wieder an.

Das Verhältnis der Ionenladungen macht während der Finsternis grosse Aenderungen durch, zeigt aber einen höchst markanten Verlauf. Bis kurz vor Totalität sind die Werte für Q (leichtes Ueberwiegen der + Ionen) ziemlich gleichmässige; darauf fällt die Unipolarität rasch ab (bis auf 0.6), um dann sehr steil zu einem überaus ausgeprägten Maximum (2.6), das kurz nach 11a eintritt, anzusteigen und ebenso steil bis zum vierten Kontakt abzufallen. Nach der Finsternis findet ein neuer Anstieg statt. Die Werte für v_+ steigen bis zum Maximum der Bedeckung erst langsam, dann steiler an; zwischen diesem Zeitpunkt und dem Ende der Finsternis, wo die + Geschwindigkeit einen recht hohen Wert erreicht, liegt eine nur durch eine kleine positive Zacke unterbrochene Depression; nach der Finsternis findet ein neuer Abfall statt. Der normale Verlauf dürfte, nach den Werten der anderen Beobachtungstage zu urteilen, ein gleichmässiger Anstieg bis zum 4. Kontakt sein, so dass die Depression mit ziemlicher Wahrscheinlichkeit auf den Einfluss der Sonnenbedeckung zurückzuführen ist.

Die spec. Geschwindigkeit der negativen Ionen zeigt einen dem beschriebenen ähnlichen Verlauf, wobei zu beachten ist, dass die Beobachtungen für v_+ später beginnen. Auf diese Weise entstehen zwei Minima, die für v unter Ergänzung der Anfangsbeobachtungen vielleicht mit anzunehmen sind. Für v_- beginnt der Abfall schon etwa eine Viertelstunde vor dem ersten Kontakt; das eine Minimum fällt reichlich ½ Stunde später; dann folgt ein Anstieg auf die gleiche Höhe, die v_- vor der Finsternis hat, und schon Minuten vor der Totalität beginnt der Abstieg zu dem sehr ausgeprägten Hauptminimum, das kurz danach eintritt und etwa 20 Minuten lang andauert. Ein rasches Ansteigen, das schneller als für v_+ einsetzt, bringt gegen Ende der Bedeckung die Werte von v_- auf ein Hauptmaximum, worauf ein neues langsames Abfallen erfolgt. Die Unipolarität der spec. Geschwindigkeiten zeigt in ihren Hauptzügen einen fast völlig parallelen, aber noch stärker markierten Gang zu dem der Unipolarität der Ladungen, resp. Ionenzahlen; d. h., dass während der Finsternis einer Zunahme der Ionenzahl eine Abnahme ihrer Geschwindigkeit und umgekehrt einer Abnahme der Ionenzahl eine Zunahme der entsprechenden Werte von v entspricht.

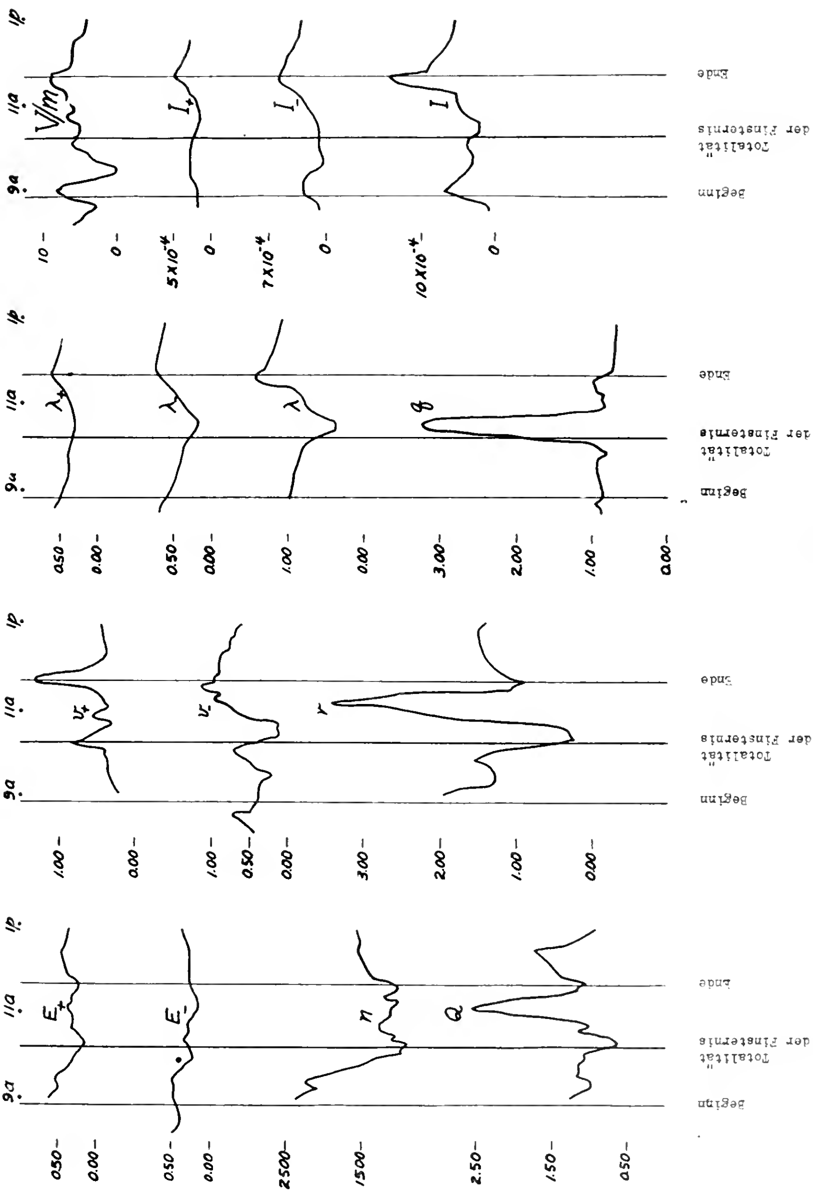


FIG. 4. Finsterniskurve der Luftelektrischen Elemente in Boa Vista (Christina), Brasilien, am 10. Oktober 1912.

Hierdurch ist wohl auch, im Gegensatz zu den bisher betrachteten Kurven von E und v, der glatte Verlauf des Ganges der Leitfähigkeit zu erklären, die an sich den Einfluss der Sonnenfinsternis am deutlichsten erkennen lässt. Der sie stärker beeinflussende Faktor ist entschieden die Ionengeschwindigkeit, nicht die Ionenladung mit ihrem weniger ausgeprägten Verlauf. Wir haben bei λ_+, λ_- und λ einen Abfall, der vor Beginn der Finsternis einsetzt und bis 10a langsam, darauf, wenigstens für λ_- und vor allem für λ, sehr steil verläuft. Das Minimum tritt $\frac{1}{4}$ Stunde nach dem 3. Kontakt ein.

Das Wachsen der Werte erfolgt für negative und Gesamtleitfähigkeit zunächst rasch, dann langsamer, wenn auch der aufsteigende Ast der Leitfähigkeits-Finsterniskurve steiler ist als der abfallende. Gegen Ende der Bedeckung wird ungefähr der Ausgangswert wieder erreicht; danach setzt ein langsamer, wohl typischer nachmittäglicher Abfall ein. Die Kurve für λ hat einige Aehnlichkeit mit einem Taifundiagramm und mit dem Finsternis-Thermogramm der Strahlungstemperatur.

Die Unipolarität der Leitfähigkeit zeigt in einer sonst ziemlich gleichmässigen Kurve (Werte < 1) eine dem starken Abfall und Aufstieg der negativen Leitfähigkeitswerte entsprechende und hierdurch bedingte positive Zacke. Dem Minimum von λ_- entspricht ein überaus hohes Maximum von $q > 3$. Trotz seiner absolut sehr kleinen Werte lässt auch der vertikale Leitungsstrom, in Folge des ausgeprägten Ganges der Leitfähigkeit, eine deutliche Beeinflussung durch die Finsternis erkennen, weniger bei den Werten von I_+, die eine sehr schwache Depression zwischen Totalität und Ende zeigen, stärker bei I_- und vor allem bei I, in deren Gang die Depression den ganzen Raum zwischen erstem und letztem Kontakt ausfüllt.

Nachdem wir hiermit die Betrachtung des Verlaufes der einzelnen luftelektrischen Elemente nach verschiedenen Richtungen hin beendet haben, scheint der Schluss berechtigt zu sein, dass sie sämtlich (mit Ausnahme des Potentials) mehr oder weniger stark durch die Bedeckung der Sonne beeinflusst wurden. Bei den Witterungsverhältnissen des Finsternistages ist natürlich eine definitive Feststellung der Beeinflussung nicht möglich, wenn auch das schlechte Wetter des 10. Oktober in Folge seiner Gleichmässigkeit eher die Berechtigung zu Schlüssen giebt, als wechselnde Bewölkung und Niederschläge vorüberziehender Depressionen oder Böen, wie sie sonst oft die Resultate der Finsternisexpeditionen getrübt haben.

Resultate anderer Finsternis-Expeditionen.

Im Anschluss an unsere oben mitgeteilten Ergebnisse seien diejenigen einiger anderer Finsternis-Expeditionen mitgeteilt. Elster[39] fand 1900 bei hohen Werten der Zerstreuung (Leitfähigkeit) eine Zunahme, Figee[40] am 18. Mai 1901 auf Sumatra eine Abnahme derselben, während van Bemmelen[41] in Atjeh keinen Effekt bei der ringförmigen Sonnenfinsternis vom 17. März 1904 erweisen konnte. Gockel[42] (?) fand für die −Zerstreuung (positive Leitfähigkeit) ziemlich konstante, aber unregelmässig schwankende Werte, für die positive Zerstreuung eine Depression. Die Unipolarität zeigte ein plötzliches Ansteigen unmittelbar nach der Totalität und einen ebenso raschen Abfall, also ein ähnliches Verhalten, wie es aus unseren Beobachtungen ersichtlich wird.

Nordmann erhielt eine Depression mit einer Phasenverspätung der (allein untersuchten) +Zerstreuung (entsprechend −Leitfähigkeit) gegen die Finsternisphasen; so trat das sehr ausgesprochene Minimum fast $3/4$ Stunden nach der Totalität ein. Die Beobachtungen von Ebert (?) ergaben zur Zeit der grössten Bedeckung eine ziemlich deutliche Minderung der −Ladung, während in Folge der Ungunst der Witterung eine Einwirkung auf die +Werte nicht festzustellen war. Elster und Geitel (?) beobachteten unmittelbar nach der Totalität sehr ausgesprochene Minima für beide Vorzeichen der Zerstreuung. Bei der (allein beobachteten) +Ionenzahl zeigte sich, bei allerdings stark schwankenden Werten, eine schwache Abnahme zur Zeit der grössten Bedeckung, während die +Ionengeschwindigkeit, nach einem Maximum ein sehr tiefes Minimum (0.11 cm) $3/4$ Stunden nach der Totalität, darauf ein schwaches zweites Maximum, ein weiteres Minimum und neues rasches und kräftiges Ansteigen zeigte. Es ist hier, abgesehen von Parallelitäten aller von Elster und Geitel beobachteter Elemente mit den unsrigen, der beschriebene unregelmässige Gang der spec. positiven Ionengeschwindigkeit dem von uns erhaltenen auffallend ähnlich.

Le Cadet (?) fand bei an sich absolut ziemlich kleinen Aenderungen ein Anwachsen der positiven Ladung und eine relativ stärkere Abnahme der negativen, so dass die Gesamtionenzahl noch längere Zeit nach der Totalität gegen den Beginn der Finsternis herabgedrückt erschien. Die Geschwindigkeit der Ionen

[39] S. l. c. 30. [40] S. *Physik. Zeitschr.* 1904, No. 5, S. 893. [41] S. *Physik. Zeitschrift.* 1905, S. 235.

[42] S. cit. 27.—Das Fragezeichen zeigt wiederum zweifelhaftes Ergebnis infolge ungunstiger Witterung an.

war verringert und hierdurch vorzugsweise eine Depression der Leitfähigkeit während der Bedeckung bedingt.

Das Verhalten der Ladung war nach Mitteilung Cireras (?), der ja am gleichen Ort wie Le Cadet beobachtete, ein dem oben angegebenen ziemlich ähnliches, hingegen zeigten die Geschwindigkeiten und Leitfähigkeiten (am Gerdienschen Apparat bestimmt) ein gerade entgegengesetztes, nämlich eine Vermehrung während der Periode, die die Totalität einschliesst. v_+ nahm sogar bis zum Ende zu; auch die absoluten Werte beider Beobachter waren trotz der Benutzung gleichartiger Apparatur ziemlich verschieden von einander. Die Zerstreuungsmessungen, die Cirera anstellen liess, ergaben ein wiederum von den übrigen Messungen verschiedenes Bild, indem die −Werte gegen Ende der Finsternis eine sehr starke Zunahme, die +Werte eine von Beginn bis Ende der Finsternis andauernde allmähliche Abnahme zeigten. Eine Abnahme der Ladung und Zerstreuung mit zunehmender Finsternis und nach der Totalität eine Zunahme, beobachtete Lüdeling (?) und zwar bei positiver Ladung des Zerstreuungskörpers (−Ionen, −Leitfähigkeit) in stärkerem Masse als bei negativer. Auch bei L. findet sich in ähnlicher Weise, wie oben betrachtet, zur Zeit der Totalität ein Auf- und Absteigen der Unipolarität der Leitfähigkeit. Süring (?) konnte keinerlei Beeinflussung der Leitfähigkeit feststellen.

Dobson erhielt für die (positive) Ionenzahl, die Leitfähigkeit und den vertikalen Leitungsstrom untereinander sehr ähnliche Kurven, und zwar ein ziemlich rasches Ansteigen der Werte im Beginn der Finsternis und eine deutliche Depression zwischen Totalität und 4. Kontakt. Brommers (?) Messungen in Wien (partielle Finsternis v. 17. April 1912) ergaben einen deutlichen Abfall (um mehr als die Hälfte) der Ladung; das Minimum trat mit der grössten Bedeckungsphase zusammen ein. Der Aufstieg endete mit dem letzten Kontakt. Der Quotient der Ionendichte zeigt ähnlich unseren Beobachtungen einige Zeit nach dem Maximum der Bedeckung einen Höchstwert. Eine sehr geringe Depression zeigten auch die Ionengeschwindigkeiten, etwas ausgeprägter die mit negativem Vorzeichen. Als Ergebnis dieser Betrachtungen erhalten wir das folgende Resultat. Unter 7 Beobachtungen der +Ionenladung (Ionendichte, Ionenzahl) fanden sich 4 Abnahmen, 1 Nichtbeeinflussung, 2 Zunahmen, unter 5 mit negativem Vorzeichen 5 Abnahmen, unter 4 Messungen der +Ionengeschwindigkeit zeigten 2 Abnahmen, 1 ein doppeltes Min.

und Max., 1 eine Zunahme. 11 positive Leitfähigkeits (−Zerstreuungs-Werte) ergaben 5 Abnahmen, 3 Nichtbeeinflussungen, 3 Zunahmen, 12 negative Leitfähigkeiten (+Zerstreuung) 8 Abnahmen, 2 Nichtbeeinflussungen, 2 Zunahmen.

Insgesamt also finden wir für die angeführten luftelektrischen Elemente eine entschiedene Neigung zu einer Abnahme im Gefolge einer Sonnenfinsternis, und zwar häufiger und fast immer ausgeprägter für die negativen als für die positiven Werte. Die Unipolarität der Leitfähigkeit scheint eine Tendenz zu raschem Ansteigen kurz nach der grössten Bedeckung zu zeigen, d. h. ganz besonders zu dieser Zeit scheint der Abfall der −Werte im Vergleich zu den + Werten bedeutender zu sein. Die von uns erhaltenen Ergebnisse reihen sich der Mehrzahl der früheren Beobachtungen an und erhöhen so die Wahrscheinlichkeit eines *vorhandenen Einflusses von Sonnenfinsternissen auf alle luftelektrischen Elemente* (mit Ausnahme der sehr zweifelhaft bleibenden Einwirkung auf das Potentialgefälle). Die Wirkung der Finsternis ruft eine Depression hervor, deren Minimum im allgemeinen der maximalen Phase der Bedeckung folgt. In dieser Hinsicht ist das Ergebnis der Sonnenfinsternis, trotz der Beeinträchtigung durch das Wetter, ein erfreuliches zu nennen, wenn auch zu wünschen wäre, dass luftelektrische Untersuchungen bei künftigen Sonnenfinsternissen fortgesetzt werden, damit die Wahrscheinlichkeit zur völligen Sicherheit wird. Es ist nämlich nicht ausser Acht zu lassen, dass die Mehrzahl aller Beobachtungen unter meist noch ungünstigeren Witterungsverhältnissen als die unsrigen gelitten haben, dass eine Einheitlichkeit der Messungen (Instrumentar u. a. m.) und daher Vergleichbarkeit der Ergebnisse nicht besteht, dass lokale Einflüsse oft ungünstig eingewirkt haben müssen (vergl. die Beobachtungen Le Cadets[43] und Cireras[44] in Tortosa am 30. Aug. 1905), dass die Anzahl der Messungen bei den einzelnen Ereignissen zumeist eine ganz ungenügende war, dass die Beobachtungen zu spät vor der Finsternis begannen und zu früh danach aufhörten, dass in Folge der geringen Reihen von Beobachtungstagen die Vergleiche zu den Normalwerten fehlen und dass häufig nur Werte eines Vorzeichens abgelesen werden konnten!

Von besonderem Interesse dürften die von uns ermittelten Resultate gerade in Hinsicht auf die Witterungslage, unter der sie erhalten wurden, auf die ursächlichen Beziehungen sein. Im allgemeinen wurde bisher angenommen, dass der Einfluss der Son-

[43] S. l. c. 31. [44] S. l. c. 5

nenfinsternis ein indirekter ist. Die durch die Bedeckung der Sonne bewirkte Abkühlung ruft eine Erhöhung der relativen Feuchtigkeit resp. partielle Kondensationen in der Finsterniszone hervor. Die Ionen als Kondensationskerne, mit Wasserdampf beschwert, verlieren an Geschwindigkeit und werden, wenn diese Geschwindigkeit unter einen gewissen Grenzwert sinkt, nicht mehr sämtlich im Spannungsfeld des Aspirationsapparates aufgefangen. Da vor allem die —Ionen zu Kondensationen Anlass geben, so wird hierdurch die vorzugsweise Abnahme der negativen Ionengeschwindigkeit, Ionenzahl, Leitfähigkeit und der negativen Komponente des vertikalen Leitungsstroms bedingt. In der Tat ergeben auch unsere Beobachtungen ein Herabsinken der spec. Ionengeschwindigkeiten unter den kritischen Wert (0.2 cm), wodurch absolut ein gewisses Herabgehen der Ladung bewirkt sein könnte, andererseits aber zeigen gerade, wie oben angeführt wurde, die Verhältnisse $\frac{E_+}{E_-}$ und $\frac{v_-}{v_+}$ ein paralleles Verhalten; damit scheidet aber die Verringerung der Geschwindigkeit als *einzige* Ursache der Minderung der Ionenzahl aus. Brommer[45] kommt nach seinen Ablesungen ebenfalls zu dem Resultat, dass das Verhalten von E durch das von v nicht erklärt wird. B. ist auch der einzige unter den angeführten Beobachtern luftelektrischer Verhältnisse bei Sonnenfinsternissen, der fand, dass die gewöhnlichen Annahmen für die Abnahme der hauptsächlichen luftelektrischen Werte als Folge der Bedeckung versagen, da die meteorologischen Elemente keinerlei entsprechende Schwankungen aufwiesen. Immerhin war die Finsternis des 17. April in Wien, während der B. beobachtete, nur eine partielle und obendrein die Witterungsverhältnisse derartig ungünstige (Bewölkungswechsel), dass man das Resultat als wenig sicher ansehen durfte. Unsere Ergebnisse, die bei einem sehr gleichmässigen Witterungstypus erhalten wurden, bestätigen vollkommen die von B. ausgesprochene Meinung. Wir erhielten zwar für Strahlungs- und Schattentemperaturen deutliche, aber besonders für letztere *absolut* überaus kleine Depressionen, die mit den bedeutenden der meisten luftelektrischen Elemente gar nicht verglichen werden können. Ueberdies ist ein Einfluss der Finsternis auf die an sich sehr hohe relative Feuchtigkeit, bei feuchtem Boden und dauerndem Niederschlag, überhaupt nicht vorhanden.

Während eine sogar sehr bemerkenswerte Einwirkung der Bedekkung der Sonne durch den Mond auf das luftelektrische Verhalten

45 S. l. c. 25, S. 11.

trotz der Bewölkung und regnerischen Witterung kaum abzuweisen sein wird, kann in unserem Falle unmöglich angenommen werden, dass diese Einwirkung indirekt durch Kondensationsvorgänge, d. h. meteorologische Faktoren, bedingt wurde. Schwer ist es danach, sich überhaupt eine Vorstellung über die Art der Einwirkung der Finsternis auf die elektrischen Verhältnisse der Atmosphäre zu machen. Eine Einwirkung durch Verminderung des Emanationsgehaltes in Folge von Abkühlung (Bodenluft), die ja überdies vorzugsweise eine Abnahme der positiven Ionen verursacht hätte, kann nicht stattgefunden haben und wurde auch nicht beobachtet; an eine Minderung der negativen Ionen infolge des Verschwindens der lichtelektrischen Wirkung ist bei dem Vorhandensein einer mittelstarken Nimbusdecke gleichfalls kaum zu denken. Auffallend ist immerhin eine grössere Aehnlichkeit, die zwischen dem Verlauf der Strahlungstemperatur und der Leitfähigkeit besteht.

Die Lösung der Frage über die ursächliche Beziehung zwischen Finsternis und luftelektrischem Verhalten bleibt der Zukunft vorbehalten, da die bisher einzige Möglichkeit einer indirekten Einwirkung verlassen werden muss. Es ist zu wünschen, dass bei künftigen totalen und partiellen Sonnenfinsternissen weitere recht komplette Messungen angestellt werden; das bei diesen Gelegenheiten so gefürchtete schlechte Wetter dürfte, falls es nicht gar zu wechselnd ist, in einigen Fällen zur Lösung des Problems sogar erwünscht sein.

Zusammenfassung der Luftelektrischen Beobachtungen.

Zusammengefasst, hat unsere Expedition nach Brasilien zur Beobachtung der totalen Sonnenfinsternis des 10. Oktober 1912 in Boã Vista die folgenden luftelektrischen Ergebnisse gehabt:

Es zeigte bei völlig bewölktem Himmel und dauerndem Niederschlag in Folge der Bedeckung der Sonne durch den Mond:

1. das Verhalten der Hertzschen Wellen, der Wert der Radioaktivität und das Potentialgefälle keine Beeinflussung,
2. die positive und negative Ionenladung eine die Finsternis ziemlich ausfüllende Depression, die durch einen leichten Anstieg unterbrochen wurde,
3. die Gesamt-Ionenzahl eine sehr markante Abnahme,
4. die Unipolarität der Ionenladung ein sehr ausgeprägtes, in bezug auf die Totalität verspätet eintretendes Maximum,

5. die positive specifische Ionengeschwindigkeit ein Herabsinken zwischen Totalität und Finsternisende,
6. die negative specifische Ionengeschwindigkeit zwei Minima, das eine zwischen Beginn und Totalität, das zweite ausgeprägtere nach ihr gelegen; beide wurden unterbrochen durch einen stärkeren Anstieg (Maximum) unmittelbar vor der grössten Bedeckung,
7. die Unipolarität der Ionengeschwindigkeit ein fast gleiches Verhalten wie 4,
8. die positive, negative und gesamte Leitfähigkeit eine während der Dauer der Sonnenfinsternis vorhandene Depression, deren Minimum der Totalität folgte (der Abfall ist ausgeprägter für das negative als für das positive Vorzeichen),
9. die Unipolarität der Leitfähigkeit, ähnlich wie 4 und 7, aber bald nach der grössten Bedeckung ein ausgeprägtes Maximum,
10. der positive, negative und gesamte vertikale Leitungsstrom bei absolut sehr kleinen Aenderungen ein ähnliches Verhalten wie die Leitfähigkeit (s. 8).

In Anbetracht der während der Finsternis herrschenden Witterung ist es nicht möglich anzunehmen, dass die Aenderungen der luftelektrischen Elemente indirekt durch die absolut sehr kleinen Aenderungen der meteorologischen Elemente bedingt wurden.

THE MEASUREMENT OF VARIATIONS IN THE EARTH'S MAGNETIC FIELD.

By H. Bell.

There does not seem to be at present any systematic method in general use for measuring simultaneously very rapid changes in all three components of the Earth's magnetic field. The suspended magnetic needle gives only an integrated value of the couple acting upon it, for since its moment of inertia is always considerable, its period is always great in comparison with such rapid changes. There is, therefore, no evidence from this source for or against rapid changes. A method is described in *Terrestrial Magnetism* (vol. 12, pp. 1-14, 1907), by Ebert, whereby rapid changes in the vertical component Z can and have been measured; the first part (I) of the present paper is to show that by a slight extension of Ebert's method we can determine with accuracy the motion of the magnetic-force vector during *normal* days, and, what is more important, determine the motion of the vector during a magnetic storm. The second part (II) proposes a method for determining with accuracy the speed of a magnetic disturbance.

I.

Let us imagine three coils of wire perpendicular, respectively, to the three components of the magnetic vector M, viz.: horizontal intensity, H, measured toward the mean magnetic north; vertical intensity, Z; and easterly component, E (always small). Let each coil be in series with a sensitive galvanometer. $\frac{E}{H}$ is a measure of the declination, and $\frac{Z}{H}$ of the dip. A change in any component, say H, gives a current in the H-coil proportional to the rate of change of flux. Changes in the other components do not affect this coil.

Let the H-coil be of radius R and have N turns of copper wire (density $\rho = 8.9$ gm./c.c., specific resistance $k = 1.6 \times 10^{-6}$ ohm/sq. cm.) of cross-sectional area a. Then the current i in amperes is given by $i = \text{area} \times N \times \frac{dH}{dt} \times 10^{-8} \div \text{ohmic resistance}$.

The mean daily change in H is a maximum about midday and varies about 5×10^{-4} c. G. s. (E. M. U.) between 11 a. m. and 4 p. m., or say 3×10^{-8} per sec. Hence,

$$i = 3 \times 10^{-16} \pi R^2 N \div (G + 2\pi k R N / a)$$

G being the resistance of the galvanometer.

Let W = mass of coil = $2\pi R N a \rho$. Hence,

$$i = \frac{3 \times 10^{-16} R W}{2a\rho} \div (G + \frac{kW}{a^2\rho}) = 1.5 \times 10^{-16} R W a \div (kW + Ga^2\rho)$$

With a given R, W and G, this is a maximum when $\frac{di}{da} = 0$, i. e., $kW = Ga^2\rho$, showing that the galvanometer has half the total resistance, and

$$i = 0.75 \times 10^{-16} R \sqrt{W} / \sqrt{G\rho k}$$

or substituting for ρ and k, we get

$$i = \frac{1}{4} \times 10^{-13} R \sqrt{W/G} \text{ ampere.}$$

Choosing R = 10 meters = 10^3 cm., and W = 2,500, G = 250,000 gm. (for a galvanometer of 100 ohms resistance) = 500 lb.,

$$i = 1.2 \times 10^{-9} \text{ ampere.}$$

The required diameter d is obtained from the relation

$$\frac{\pi d^2}{4} = a^2 = \frac{kW}{\rho G}$$

which leads to d = 1.6 mm.

Granted that these dimensions are practicable and measurable, this method has the advantage over the suspended-needle method of being less liable to go wrong from mechanical or temperature disturbances, as the coil can be deeply buried in the Earth. On the other hand, it gives only the rate of change of element, which would have to be continuously integrated for questions requiring absolute values.

It is, however, in magnetic storms where quick changes occur that the method shows up to best advantage. There we sometimes have changes in the elements one thousand times as great as the values just assumed, which, allowing for the greater resistance of galvanometer for rapid work, gives us currents of the order 10^{-7} amp. We could, therefore, use a high resistance Einthoven galvanometer of very short period and get the simultaneous rapid changes in the three components of the magnetic vector. For example, at the time of an eclipse we could find in what way the lines of force actually bend as the shadow passes.

II.

Imagine two horizontal coils distant D apart along the x-axis, each of area A and having a resistance R ohms due to N turns of copper wire. Let them be in series with a galvanometer (G ohms) and be oppositely wound.

When, now, a magnetic storm (series of waves) passes along the surface with a velocity whose x-component is v, then, representing the vertical component of the magnetic flux by

$$Z = Z_0 \cos b\,(x - vt),$$

the E. M. F. (E_0) due to the coil at the origin is

$$\text{area} \times N \times \frac{dZ}{dt} \times 10^{-8} \text{ volt} = ANZ_0vb \sin b\,(0 - vt) \times 10^{-8} \text{ volt},$$

while E_1 due to the other coil, is

$$-ANZ_0vb \sin b\,(D - vt) \times 10^{-8} \text{ volt}.$$

Together we have a current in amperes

$$a = i_0 + i_1 = 2ANZ_0vb \sin\frac{bD}{2} \cos b(\frac{D}{2} - vt) \times 10^{-8} \div 2G$$

where the resistance $2R$ of the two coils has been put equal to G for a maximum effect.

If now we have, at the origin, a second circuit comprising a galvanometer of resistance G and a coil of resistance G in the same plane, and of the same dimensions as either of the other coils, then the current i_2 in this third coil will be

$$i_2 = -ANZ_0vb \sin vbt \times 10^{-8} \div 2G.$$

Thus, if $(i_0 + i_1)_{\text{max.}}$ and $(i_2)_{\text{max.}}$ denote maximum values, we have, on writing the frequency $n = \dfrac{bv}{2\pi}$

$$(i_0 + i_1)_{\text{max.}} = 2(i_2)_{\text{max.}} \sin\frac{bD}{2} = (i_2)_{\text{max.}} \sin\frac{\pi n D}{v}.$$

Now, by section 1 above, $(i_2)_{\text{max.}}$ can easily be of the order of 10^{-8} ampere for magnetic storms. Also v may be taken[1] as of the order 2×10^7 cm./sec. Assuming $D = 10$ km. $= 10^6$ cm. and n, say, 1, we have

$$(i_0 + i_1)_{\text{max.}} = 2(i_2)_{\text{max.}} \sin\pi/20 = \text{say, } 3 \times 10^{-9} \text{ amp.}$$

a quantity measurable with accuracy.

If, therefore, we photograph the galvanometer readings for $i_0 + i_1$ and i_2 on the same photographic sheet, a comparison enables us to determine v. If the curves are not sine curves, the procedure would be more complicated as regards the calculation.

[1] See paper by L. A. Bauer, in *Terr. Mag.*, v. 15, p. 226, 1910.

From the preceding it appears that with three coils and two galvanometers we can determine the speed of a disturbance in a given direction. With two such sets (the second set along the y axis) we can determine the other component, and thus have the (surface) direction and speed.

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